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A MEXICAN BOY TWISTING CENTURY PLANT FIBER INTO TWINE (see page 313)

Rubber as a Colloid*

Remarks Upon the Chemical Structure of the Material in Various States

By D. F. Twiss

WHEN Graham first definitely grouped substances into crystalloids and colloids he expressed his consciousness of the fact that such distinctions are not absolute and that there is no abrupt transition between the two types; substances of intermediate characteristics are known which form the links necessary to demonstrate the continuity between the two states.

Rubber is so completely and typically colloidal that it is a matter of some difficulty to decide what details should be selected in order to give briefly a general indication of its colloidal character. The difficulty is increased by the fact that so many of the definite results of scientific investigation refer to simpler artificially prepared colloids.

Colloidal substances are commonly classified into suspensoids and emulsoids. In the former, finely dispersed particles, microscopic, ultramicroscopic or even smaller, exist in a state of more or less stable suspension. In the latter the conditions are similar, except that the substance of the particles is fluid and is soluble to a considerable extent in the dispersion medium.

RUBBER LATEX.

It is a rather striking fact that natural rubber makes its first appearance in a condition which may be described as doubly colloidal. The latex obtained by tapping various rubber trees is a milky fluid containing minute globules of a colloid, probably rubber itself (Hinrichsen and Kindscher, *Jour. Soc. Chem. Ind.*, 1910, 34), in a state of colloidal suspension in an aqueous fluid or serum. In the latex from *Hevea brasiliensis*, which is the origin of all Para rubber, wild and cultivated, the globules are microscopic and range in diameter from 0.5 to 2 μ in diameter; they show a distinct Brownian movement. Other less common latices hold the rubber in varying degrees of dispersion; *e. g.*, in the latex of *Funtumia elastica* the particles of rubber are smaller and their Brownian movement is therefore more marked, although the general phenomena are comparable with those in *Hevea* latex (Spence, *Jour. Soc. Chem. Ind.*, 1908, 1123).

Most solid substances in contact with water become negatively charged, and therefore the particles of most colloidal suspensions in which water is the dispersion medium will, in an electrical field, tend to migrate from the cathode towards the anode. Positive suspensoids are of course also known but are in the minority.

If a quantity of rubber latex, dialysed or otherwise, is submitted to the action of an electric current, the globules wander towards the anode so that the liquid gradually becomes clear at the cathode, while at the anode the amount of rubber in suspension is considerably increased. This behavior, which forms the basis of a patented method for the separation of rubber from latex, proves rubber globules in latex to possess a distinct negative charge. Rubber latex therefore is a negative suspensoid and it is not surprising that the precipitation of rubber from *Hevea* latex exhibits certain analogies with the precipitation of such substances as clay or arsenious sulphide from colloidal aqueous suspension. The precipitation of negative suspensoids such as these is greatly accelerated by the addition of acids, and as is well known, most of the rubber produced to-day is separated from its latex by the addition of small quantities of acetic acid; as is mentioned below, this may not be due merely to the effect of hydrogen ions on the negative suspensoid. Alkalis on the other hand increase the stability of negative suspensoids, including rubber latex. The relative effect of acids and alkalis suggests that the cation is the agent involved in the acceleration of the precipitation of the disperse phase of the negative suspensions, and this is confirmed by the relative effect of salts of univalent, bivalent, and trivalent metals, the effectiveness increasing to a quite disproportionate extent with the valency (see Schulze, *J. prakt. Chem.*, 1882, xxv., 431; 1883, xxvii., 320; Hardy, *Z. physik. Chem.*, 1900, xxxvii., 385; Freundlich, *ibid.*, 1903, xlv., 144).

Hevea latex as a colloidal suspension can be freed from soluble saline constituents by dialysis through a suitable colloid membrane; after purification by prolonged dialysis through a collodion film until its electrical conductivity due to saline impurities is reduced from 3300×10^{-12} to that of ordinary distilled water, it is almost unaffected by salts of univalent metals, whereas salts of the bivalent alkaline-earth metals

cause flocculation of the rubber if above N/1 concentration and salts of the heavy bivalent metals (which are also frequently acidic on account of hydrolysis) and of trivalent metals such as iron and aluminium cause flocculation at approximately N/20 concentration; acids cause the separation of the rubber from dialysed latex at approximately N/2 concentration (V. Henri, *Comptes rend.*, 1907, cxliv., 431). The necessary concentrations will naturally be lower for the crude latex because this already contains certain inorganic salts which will facilitate the separation of the rubber. According to the concentration and the specific effectiveness of the coagulant, the rubber may separate as a loose flocculent mass or as a tenacious elastic cake, the former probably representing an incomplete stage of the latter; in either case separation is preceded by a cessation of the Brownian movement due to the increasing size of the particles by coalescence. As the quality of the finished raw rubber to a considerable extent is dependent on the nature of the coagulum obtained, the conditions of coagulation and the selection of a coagulant are matters of importance, and in rubber plantations a more or less standardised coagulation process is adopted.

From the behavior of various colloidal suspensions it is known that the presence of an additional colloidal or emulsoid substance can increase the stability of the suspensoid, and indeed this knowledge is applied in the production of silver bromide emulsion for photographic plates and in the stabilising of colloidal solutions of metals, *e. g.*, palladium and platinum in water by the addition of such substances as gelatin or sodium protalbate or lysalbate (decomposition products of albumin).

Hevea latex contains protein matter among other substances, besides water and rubber, and the presence of this likewise increases the stability of the suspensoid, the dissolved protein matter acting as a protective colloid.

Dilution naturally reduces the effectiveness of the protective agent and the addition of water to latex in consequence accelerates the spontaneous separation or "creaming" of the globules.

The addition of a reagent capable of removing the protein by precipitation will evidently also increase the rate of flocculation or coagulation of the suspensoid. The protective agent is not of albuminoid character in all cases, *e. g.*, latex from *Funtumia elastica* contains no albuminoid but a peptone, which serves a similar purpose, and in this case peptone precipitants such as formaldehyde will cause coagulation, although this substance actually increases the stability of *Hevea* latex (Fickendey, *Z. Chem. Ind. Kolloide*, 1910, viii., 43).

The phenomena surrounding the coagulation of rubber latex are however further complicated by concurrent, but to some extent independent, processes capable of effecting a similar result. Although acids of a sufficient concentration can unquestionably effect the coagulation of latex by their own influence, the effect of the very small proportion of acetic acid used on the plantations is not a simple acidic effect. Ordinary raw latex which has been sterilised by heat does not behave normally with the customary proportion of acetic acid, but on the addition of a little fresh latex, the usual coagulation occurs. This might be due to the presence in crude latex of micro-organisms capable of converting the accompanying dissolved carbohydrates into lactic acid (Eaton, *Jour. Soc. Chem. Ind.*, 1918, 99a). There is evidence however that the spontaneous coagulation cannot be attributed entirely to bacterial action of this kind and that except under unusual conditions it must be essentially an enzyme process analogous with the setting of milk by rennet (Barrowcliff, *Jour. Soc. Chem. Ind.*, 1918, 48r; Whitby, *Agric. Bull. Fed. Malay States*, 1918, vi., 374). It is therefore probable that the very small proportion of acetic acid used on the plantation accelerates the process by a favorable influence on the activity of the enzyme; with a gradually increasing proportion of acid a point of minimum effect is observed, due probably to a decomposition of the enzyme; with still higher concentrations the rate of coagulation again begins to increase, the effect then being that of an acid on a negative suspensoid.

Reference should be made to the possibility of coagulating latex by altering the nature of the dispersion medium; the addition of acetone or alcohol or mixtures of these with other liquids has frequently been suggested for the purpose of separating the rubber in a coherent mass.

RAW RUBBER.

When masticated rubber is immersed in a solvent, the latter is slowly absorbed, the rubber swelling enormously and finally, especially if the process is aided by agitation, yielding a colloidal solution of high viscosity. Some solvents such as carbon bisulphide, chloroform, and benzene, yield almost transparent, clear solutions, but with others such as shale naphtha, petroleum spirit, and ether, the solution obtained is milky in appearance. This turbidity is not merely due to the difference between the refractive index of the solvent and of the suspended particles but is caused by the presence in rubber of constituents of different solubility, so that whereas the rubber is almost entirely soluble in the first-named liquids, it is in reality only partially soluble in the latter set, the insoluble portion becoming finely dispersed throughout the solution, and remaining in colloidal suspension; the dissolved portion of the rubber in this case doubtless exerts a protective influence on the colloidal suspension. Even in the apparently clear colloidal solutions, *e. g.*, of the emulsoids gelatin and agar-agar, the ultra-microscope is able to detect discontinuity due to the presence of submicroscopic particles, and clear solutions of rubber are no exception, the particles of dissolved rubber being too small for detection by direct microscopic examination although manifest from the Tyndall effect and visible in the ultra-microscope. The turbid solutions of rubber in petroleum spirit are to be regarded as colloidal solutions of a lower degree of dispersion than the clear solutions in carbon bisulphide, the dispersed particles being probably in part microscopic, while the so-called "vulcanising solutions" of the manufacturer consisting of rubber solution with sulphur and perhaps litharge in more or less permanent suspension are still coarser in nature.

Although rubber latex is closely comparable with the ordinary suspensoid colloids, rubber itself is an emulsoid. Emulsoids are as a rule much more viscous than suspensoids and the proportion of dispersed substance to medium is often much higher; the more or less rigid colloidal substances or gels such as gelatin, agar-agar, and gelatinised silicic acid are believed to retain the emulsoid nature and to consist of a colloidal substance dispersed through a colloidal medium, the result being a sponge-like or cellular structure, too fine however to be detected by ordinary means. Raw rubber may be considered as a fairly extreme case in which the rubber hydrocarbon is in a fine state of dispersion throughout a medium, probably consisting in part of the protein matter from the latex; however, as rubber freed from protein matter still retains its typical consistency, the emulsoid state must be attributed mainly to the presence of rubber in at least two forms of different molecular weight, or at any rate of different molecular condition, the rubber thus supplying not only its disperse phase but also its own dispersion medium. Other peculiarities in the behavior of rubber confirm this lack of uniformity, *e. g.*, the "freezing" or stiffening of raw rubber, which may be compared with the very marked increase in viscosity of gelatin solutions at lower temperatures, is accompanied by the development of a turbid appearance; this is easily observable in smoked sheet rubber which has been kept in the cold for any length of time. Purified gutta and balata pass from an opaque to a semi-transparent appearance at higher temperatures and even solutions in benzene show an analogous reversible gelatinisation and concurrent opalescence under similar conditions. In each case the phenomenon is explicable by a lack of uniformity, which is to be attributed to the variable magnitude of x in the formula $(C_2H_4)_x$ for any sample of pure rubber, balata, or gutta. The effect of heat, light, or acids in producing a marked reduction in the viscosity of rubber solutions may be due to alteration either in the colloidal condition or the molecular condition, or indeed in both. The lower viscosity of solutions of gutta percha and balata, and the manner in which these substances separate from solution in some solvents, suggests that the hydrocarbon of gutta and balata has a less complex nature than the hydrocarbon of rubber.

ADSORPTIVE POWER OF RUBBER.

A striking property of the emulsoids is their power of condensing or adsorbing substances at surfaces of contact with another phase; the adsorption of dyestuffs from solutions by fabrics or by charcoal and of gases by charcoal are examples of this characteristic. When colloidal arsenious sulphide is precipitated from aque-

*Address before Birmingham Section, Society of Chemical Industry. From the *Journal of the Society*.

ous suspension by the addition of electrolytes, the precipitate is found to contain some of the precipitant ion in the adsorbed condition and removable only with difficulty (Whitney and Ober, *J. Amer. Chem. Soc.*, 1902, xxi, 842). It is therefore not surprising to find that when salts or acids are used to aid the coagulation of rubber latex, these tend to be retained tenaciously by the rubber conglomeration and to resist removal during subsequent washing. This supplies an obvious reason for avoiding the use of non-volatile salts or of mineral acids in artificial coagulation and for the use of as small a quantity of coagulant as possible, whatever its nature. Reference has already been made to the presence of protein matter in ordinary rubber latex and to its protective effect on the suspension; such protective effect is actually dependent on the adsorption of the protein at the surface of the globules and as a consequence washed and dried raw rubber contains several units per cent. of protein matter; the presence of a similar proportion of resinous material may be due to a similar cause; the occasional discovery of a very appreciable quantity of *l*-methylinositol, a sugar-like substance soluble in water (Pickles and Whitfield, *Proc. Chem. Soc.*, 1911, 54), adsorbed from the latex and retained in spite of washing process, is perhaps more unexpected.

If the newly formed rubber conglomeration is allowed to remain in a moist condition for several days, the protein matter undergoes partial putrefactive decomposition with formation of basic substances and amino-acids which remain adsorbed in the finished washed and dried rubber and exert a very marked effect in accelerating the rate of vulcanisation; indeed the slightly greater variability in the rate of vulcanisation of plantation rubber as compared with the Brazilian product is largely due to the varying amount of such adsorbed vulcanisation catalysts. In view of these facts it is hardly surprising that on soaking freshly coagulated rubber in caustic soda solution some of this is adsorbed, with the result that the rate of vulcanisation is greatly increased. Regenerated rubber in the production of which alkali has been used, in spite of careful washing often retains sufficient alkali to affect the rate of vulcanisation of mixings containing it.

The behavior of rubber as a colloid is so general as to have led to doubts as to whether vulcanisation is a chemical process at all (Höhn, *Gummi-Zeit.*, 1899, xiv, 17, 33; Ostwald, *Z. Chem. Ind. Koll.*, 1910, vi, 136; vii, 45; see also *Jour. Soc. Chem. Ind.*, 1917, 787). When the excess of sulphur remaining uncombined after vulcanisation is removed by prolonged treatment with acetone, the rate of extraction is such as to indicate that some of this sulphur at least, has been adsorbed (Spence and Scott, *Jour. Soc. Chem. Ind.*, 1911, 816) and not merely dissolved by the rubber. Adsorption certainly must play a considerable part in the changes which rubber undergoes during vulcanisation, but it is now fairly generally accepted that the combined sulphur really is in a state of chemical combination. The adsorption process, however, does not cease at the free sulphur stage, because in the vulcanised product the amount of combined sulphur may vary to a remarkable degree and gives little indication of the formation of any definite compound; yet even in a lightly vulcanised product the whole of the rubber has lost the characteristics associated with it in the raw condition and cannot be regarded as a simple mixture of vulcanised and unvulcanised material. In order to explain these peculiarities, it appears necessary to suppose that the part of the rubber which combines with the sulphur is adsorbed irreversibly into the remaining bulk, thereby producing in it a colloidal—and possibly polymeric—change comparable with the setting of a solution of silicic acid or the coagulation of albumin. Vulcanised rubber must be regarded as still retaining the emulsoid condition although in a more rigid and more stable modification than raw rubber. In vulcanised rubber the adhesiveness of raw rubber has disappeared almost entirely and working between steel rollers merely reduces the material to crumb, whereas raw rubber under similar treatment forms a coherent sheet which with further working becomes gradually softer and more plastic, this effect probably being due to the influence of the mechanical treatment on the emulsoid structure. The operation of reclaiming or regenerating raw rubber as commonly practised consists in so treating the vulcanised rubber—generally with heat—as to modify its colloidal characteristics and to restore to it some of the adhesiveness associated with raw rubber.

SOLVENT POWER OF RUBBER.

On account of the considerable power of rubber as a solvent the rate of entry of gases into its surface will not depend so much on the molecular velocity of the gas as on the specific rate of solution. Hydrogen

will diffuse through a fine aperture or fissure much more rapidly than the heavier carbon dioxide, but the rate of diffusion of carbon dioxide through a rubber septum is much greater than that of hydrogen and the relative rates of other gases do not stand in any simple relation with their molecular weight. Graham's law of diffusion therefore does not apply. The processes involved will be solution (or possibly adsorption) at the surface, subsequent adsorption into the body of the rubber, and finally escape at the far side, thus completing a steady flow of diffusion through the septum.

From the general phenomena of dialysis, it is well known that colloids do not penetrate gels, or at any rate penetrate them less rapidly than do crystalloids, which are able to diffuse through them readily.

The migration of dissolved uncombined sulphur from the interior of a soft vulcanised rubber to the surface, causing "sulphuring up" or "blooming," is an example of the permeability of a gel to a non-colloid substance. Rubber, as a colloid should be capable of acting as a semi-permeable membrane under suitable conditions, and an interesting application of this idea has been mentioned in a patent for the purification of rubber; the remarkable alteration in rubber caused by vulcanisation is here emphasised by the use of soft vulcanised rubber as a semi-permeable membrane for the dialysis of dissolved raw rubber; if on one side of such a membrane there is placed a solution containing rubber and sulphur in any suitable solvent and on the other side a quantity of the pure solvent, the dissolved rubber will not penetrate the vulcanised rubber sheet, but the dissolved sulphur will gradually pass through so that by continually supplying fresh solvent the whole of the sulphur may be extracted from the solution (Debaugé, *Fr. Pat.* 426,457, *Jour. Soc. Chem. Ind.*, 1911, 968). Hancock's well-known method of vulcanisation by immersion of rubber in a bath of molten sulphur also obviously depends on the power of sulphur to penetrate rubber.

Despite the advances that have been made, our knowledge of the nature of colloids is still so limited that much of the behavior of rubber and other natural colloids remains obscure. One of the greatest obstacles in the way of the production of synthetic rubber is the colloidal nature of the material. The problem is not merely to produce a substance of known molecular weight and structure, as was the case with indigo, because the required material is of undetermined molecular magnitude and is less desirable in a pure condition than when containing certain so-called impurities. Recent reports on the synthetic rubber manufactured in Germany during the last few years suggest that these difficulties have been experienced to the full and that despite the extraordinary incentive the results have been such that although the products obtained resembled raw rubber so far as to be of use for vulcanite and the less elastic forms of soft rubber, the general successful replacement of natural rubber in rubber goods has not yet been accomplished.

DISCUSSION.

Dr. Twiss, in reply to questions, said that under the customary plantation conditions as to concentration of acid and proportion of rubber in the diluted latex, the coagulation process was in all probability primarily due to the enzyme the activity of which was increased by the acid present. Acetic acid was the acid commonly used, but acids generally were capable of hastening coagulation and lactic acid was no exception to this rule. Owing to the shortage of acetic acid during the war considerable attention had been paid to the possibilities of "spontaneous" coagulation, and this method had been shown to be of much promise and would probably retain a certain amount of favor even although an improved supply of acetic acid became available. The amount of saline matter in latex was relatively small and the proportion of rubber, which was generally adjusted to a definite standard by suitable dilution before coagulation, could be determined more easily by the hydrometer than with an ultramicroscope. In the combination of rubber and sulphur as effected in vulcanisation there were no sharply defined stages and the only indications of the formation of a definite compound appeared when the rubber hydrocarbon was chemically saturated with sulphur, this condition being represented by the formula $C_{20}H_{32}S_2$. The representation of the rubber molecule, whether vulcanised or not, by a cyclic structure was already customary; there appeared to be no reason now for doubting that during vulcanisation chemical combination really did occur between the rubber and at least part of the sulphur. As the vulcanisation process was exothermic, although only feebly so, the heat of combustion of vulcanised rubber would be less than that of its constituents in the free state. It was generally accepted that the rate of diffusion of a gas through rubber was de-

pendent on the solubility of the gas in the rubber and that the molecular velocity of the gas was relatively unimportant in this direction. The process of dialysis to which reference had been made would not be capable of effecting the re-conversion of vulcanised rubber into raw rubber because not only would chemically combined sulphur resist separation in this way, but vulcanised rubber could not be obtained in solution without such drastic treatment as would seriously alter its nature. It was unlikely that inorganic salts would be able to diffuse through a vulcanised rubber membrane although water would do so with extreme slowness.

Substitute for Rubber-Insulated Wires

In *Elekt. Zeits.* a German writer describes tests made on various "war-wires," particularly in respect of mechanical strength and resistance to moisture and heat. The insulation on the wires investigated consisted of regenerated rubber, bitumen or a series of layers of impregnated paper strip wound on spirally. The last-named system of insulation gives particularly good results, equal in fact to the results given by the best pre-war, rubber-insulated conductors. Compared with the latter, paper insulation does not "age" appreciably; it is less affected by prolonged heating and has great uniformity of quality. The substitutional insulations considered do not involve the use of imported raw materials and it is considered that they may continue to be used after the war. With the use of substitutes for insulation the acceptance tests for the latter had to be relaxed and as from August, 1917, the V.D.E. rules stipulated a $\frac{1}{2}$ -hour test at 500 volts after 1 hour's immersion in water, for wires which had formerly been required to stand $\frac{1}{2}$ hour at 2,000 volts after 24 hours' immersion. The new rules obviously leave a very small margin of safety in wires which are used in damp situations and at 220 volts above earth. The present tests were made on wires of 1.5 mm.² section and overall diam. from 4.5 to 5.0 mm.; one of the types of wire tested was Meiwowsky's "M-wire" (with impregnated paper insulation): no particulars are given concerning the insulation of the other wires. The M-wire yielded an insulation resistance of 6,500 megohms per metre (unaffected by 24 hrs. submersion); and a breakdown voltage of 8,000 volts after 24 hrs. immersion in water at 20° C. (compared with 300 to 600 volts for the other war-wires tested). The insulation resistance of M-wires was not lowered appreciably and the breakdown strength was not decreased seriously by repeated bending. Even when the thickness of paper on the M-wires was halved (making the overall diam. 4 mm. for a copper section of 1.5 mm.²) a breakdown voltage of 2,600 to 3,500 volts was obtained after 24 hrs. immersion. Almost absolute uniformity of insulation is obtained in M-wire, compared with great irregularity (due to impurities, fissures, and excentricity) in the breakdown strength of other war-wires, tests on which show the ratio of minimum to maximum breakdown voltage to vary from 1:2.4 to 1:30.6. The wires insulated by bituminous "substitutes" became quite excentric with the insulation after 20 hrs. at 50° C. Regenerated rubber is less objectionable in this respect. Paper insulation is unaffected mechanically and loses only 20 per cent. breakdown strength at 75° C., as compared with 30 per cent. in regenerated rubber and 73 or 74 per cent. in bituminous insulation.—*Science Abstracts.*

Tests for Trainmen in Germany

THE Saxon State Railways are now submitting their engine-drivers and other responsible train officials to certain tests in their psychometric laboratory at Dresden. According to the *Zeitung des Vereines deutscher Eisenbahnverwaltungen* (October 2), the tests comprise strength of will and endurance, and fatigue where there is physical strain. The Dubois ergograph is used for the purpose, the object being to trace a fatigue curve. The forearm rests on the table; over the middle finger is run a catgut loop, which passes over a pulley, the other end of the gut supporting a weight of from 4 to 8 kg., according to the suitability of the subject. When the middle finger is bent the weight is raised, and when relaxed again the weight is dropped, the process of this motion being traced on a recording drum. With every stroke the drum advances 1 mm., and every two seconds a clockwork movement records a time mark, so that fatigue in terms of time can be read from the final curve. In addition to giving the mean efficiency in metre-ergs per second, the ergogram also shows the degree of fatigue (i. e., diminished efficiency) per minute, as well as the number of lifts which the subject has to make in order to do 1 metre-kilogram of work. The system has been said to give satisfactory results as regards the selection of men for the proper posts.—*Nature.*

The Shell Builders—I

A Brief Introduction to the Study of Conchology

By R. W. Shufeldt, M.D.

WITHIN the entire range of biological research, including the collecting of specimens in any particular department, there is no single science that possesses a more abiding interest for either the amateur or the professional naturalist than the science of conchology, which takes into consideration the study of shells. That science nowadays, however, has a much wider scope than this, including, as it does not only shells but all that falls to the researches upon the Mollusca generally.¹ At present this group is made to include some fifty thousand or more different animal forms, and these are of the very widest distribution. They occur in every part of the world, and in some quarters far invade the circumpolar regions, hundreds of species being terrestrial by nature and thousands of others oceanic or aquatic; some are more or less amphibious.

A century or so ago we knew little or nothing about the shell-building mollusks, while since those times science has described and named an enormous list of them—a list which exceeds that of all the known species of mammals and birds in the world put together.

In the matter of size, they pass from such ponderous forms as the giant clams of Australia—a specimen of which may weigh a quarter of a ton and possess a width of four feet or more—to the limpets of the group which it requires the aid of the microscope to see. Some of these live on the surface of the sea, while others normally thrive thousands of feet below it.

With respect to locomotion, we find, throughout the group, species here and species there that naturally present every form of it. Plenty of them dive, swim, or float; a few are capable of flight; many are expert burrowers, while crawling, climbing, and leaping forms are well represented by different species.

When studied from an economic standpoint, with respect to man's needs, interests, welfare, or pleasure, it is well known that mollusks play a very important part in several of these lines. Many forms are used as food from one end of the world to the other, as is seen in clams, oysters, scallops, and the like, while many species make for improved sanitation through constantly preying upon certain disease germs in nature and their consumption of organic matter undergoing putrefaction. The part played by pearls and mother-of-pearl, the Tyrian dyes, sepia, inks, and other products derived from mollusks, is too well known to demand especial comment or description.

Apart from these utilitarian questions, mollusks are being studied by hundreds of people all over the world. Some are devoting themselves entirely to the morphology of the various molluscan animals that reside in the shell or shells. With respect to the latter, magnificent collections are to be found in both private and public museums—while some individuals who have devoted their lives to the collecting of shells alone from every part of the world, possess conchological cabinets of untold value and importance.

There are shells of great rarity that command fabulous prices in the market; and perhaps one of the most interesting experiences one may have in life is to be present at an auction sale of some unique and valuable collection of shells. "The Golden Age of Conchology was reached," says Julia Ellen Rogers in her "Shell-Book," "in the middle of the last century, when Hugh Cuming returned from cruising among the islands of many seas, bringing as spoils of his wanderings thousands of shells of the Tropics, the largest

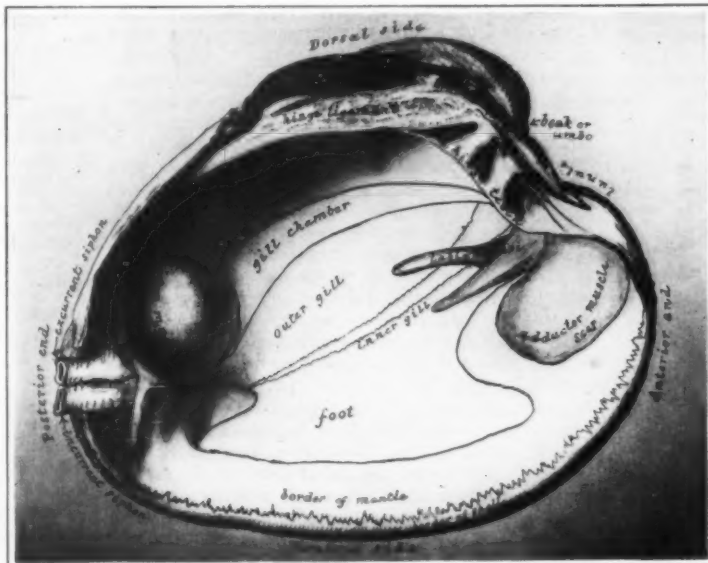
and handsomest to be found in the world. He had twenty-five hundred different species of marine shells, and five hundred species of land shells. Such forms find refuge among grooves of many-colored corals and sea-weeds; the air-breathers hide among tropical vegetation, unseen because as gaily striped as the flowers. Many of these splendid shells were

speculators. These were centers of excited competition, where prices of rare and beautiful shells reached surprising heights."

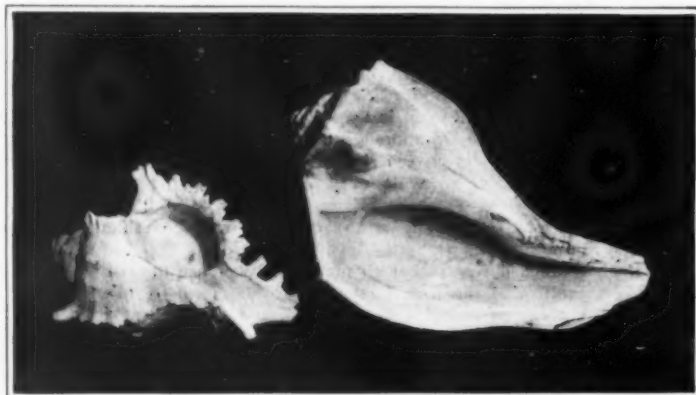
It is needless to state that a great many—indeed thousands—of fossil mollusca have been described, and among them no end of fossil shells. Many of these are now quite extinct; while taken in their entirety, in the several successive geologic horizons—as the latter become more and more recent—such fossils shed much light upon molluscan evolution, and upon the relationships to existing types. Of such species we possess an extremely imperfect knowledge, and there is but little left for us in our studies of them beyond the grim satisfaction of bestowing upon the undescribed species new names. As a matter of fact, this is about all that has been accomplished with respect to hundreds of present-day molluscan forms. Take the habits, the reproduction, the anatomy and physiology, the histology, the special senses of scores upon scores of existing molluscs—what knowledge have we upon such subjects? Surely very, very little; and in the case of the majority of the chapters of the book as a whole we are in a state of the most profound ignorance. This does not imply, however, that nothing has been accomplished in such fields; as a matter of fact, we have a very thorough and wide knowledge of a great body of biological facts as applied to the Mollusca—moreover, an exceptionally fine literature exists having reference to this assemblage of forms as a whole. In the case of some species, we are more familiar with their morphology than with their habits and physiology, to say not a word as to what we have acquired with respect to all that molluscan psychology may have in store for us. These subjects are of such extent and so thoroughly technical in character, that to touch upon them here, even in a popular way, would be quite impracticable. This does not apply to conchology in a more restricted sense,—that is where shells alone are to be touched upon, as is the case with the present article. It may be noted in passing, that not only have the external parts and characters of shells all been named and described, but the general anatomy of the "soft parts" of a very large number of molluscan animals is known. Many special works have been published on such subjects, and these may be readily consulted in any of our large scientific libraries.

Shells fall mainly into two general groups, and these have been designated as the *univalves* and the *bivalves*; some authors at hand also speak of *multivalve* shells. Univalve shells are the *spiral* form, while the bivalves are after the clam order, the shell being in two parts or valves. We show a common species of whelk, which is a typical univalve shell. One can easily appreciate the fact that such a shell has a *central axis*, and this axis has been named the *columella*. Around it winds the balance of the shell, and these coiled whorls are known as the *spire*, which latter terminates anteriorly as the *apex* of the shell. In the vast majority of shells this coiling is to the right, and such specimens are called *dextral* shells; should the coiling be to the left, they are called *sinistral* shells—the cut demonstrates these differences. Some univalve mollusks have a channel passing round between the coils of the spire, and this is called the *suture*; it usually terminates at the large initial coil or body whorl, so named because we find in it the body of the animal occupying the shell.

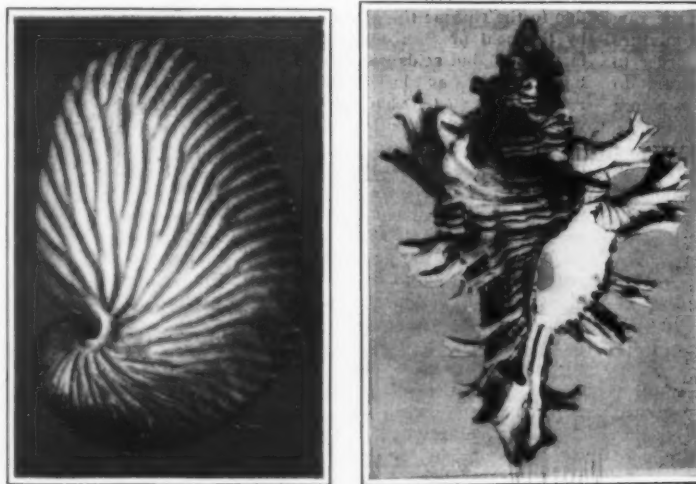
The opening into this sort of shell is called its mouth or *aperture*, the free margin of which is the *outer lip*. The aperture is continued out over the prolongation from the body whorl, which continuation is



Left valve of hard clam shell, reduced one-fourth; showing location of parts in a typical bivalve shell



Dextral and sinistral univalves. Branched Murex (*Murex ramosus*; left, dextral); Knobbed Whelk (*Fulgur carica*; sinistral; at right)



Left, Paper Nautilus (*Argonauta argo*) of the Mediterranean; left lateral aspect. Right, Rose-branch Murex from China (*Murex palma-rosa*)

absolutely unknown to science. The tremendous effect they produced upon the shell collectors of Europe cannot be described. Magnificent private collections represented the grand passions of many wealthy and ambitious amateurs. Auction sales were patronized by persons of high social standing, noted conchologists, and shrewd

¹Mollusca is from the Latin adjective, which is applied to anything soft. In this connection it refers to the rightful animals living in shells, and to those naked forms that do not build shells, as the slugs and others.

termed the *anterior canal*, and the *inner lip* or *columella* may be produced along the border of this. Often the whorls are flattened all the way around to the apex, and when this is the case the angle thus formed, running parallel to the suture, is designated as the *shoulder*.

In live univalve shells we have a tough, pubescent skin overlying the whorls which is the *epidermis*, while the *operculum* is the horny plate that closes up the aperture when the animal draws itself completely into the body-whorl. A fine enamel usually lines the interior of such shells as these, the balance of the structure being mostly composed of a fine calcium. This dense, limy deposit fills in between the enamel and the epidermis and constitutes the chief shell structure.

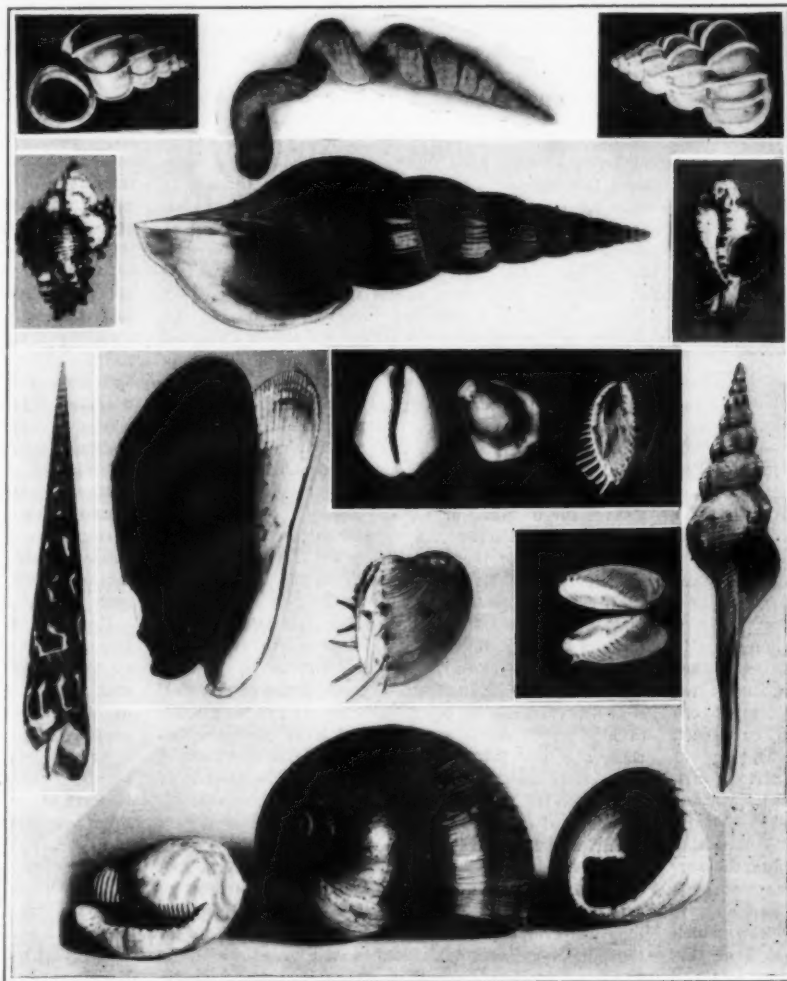
With varying degrees of perfectness, mollusks possess *eyes* with which they can see; organs in which reside the sense of *touch*; an *osphradium* with which it is supposed they can *smell*, and other structures by means of which they can detect sound or *hear*. The sense of *taste* is likewise present in some species. It goes without the saying that the presence of all these special senses in mollusks, be they highly or poorly developed, points to an efficient *nervous system* in them; this is readily proved through dissecting some thoroughly specialized species wherein all the structural parts are highly organized for molluscan morphology. In such a form we should study the *mantle*, the *siphon*, the *foot*, the *proboscis*, the *reproductive glands* of both sexes; the *gills*, the *heart*, the entire *internal tract*, together with the *kidney* and the *liver*, and several other parts of interest and importance.

As already pointed out, there are a great many thousands of different species or kinds of shells known to science; and, as is the case with all such objects, the mind cannot well grasp either their number or their relationships until they be duly classified and the classification adopted be based upon some natural scheme. Such a scheme, to be of any practical value, should primarily take into consideration the entire scope of molluscan morphology,—that is form and structure. To some extent, this may be verified or checked by habits, geographical distribution, and the fact as to whether any particular species or group of species is terrestrial, amphibious, or pelagic.

A very fair provisional classification divides the Mollusca into four principal groups. First we have the Univalves and Chitons, this group contains the Class *Gastropoda*, in which we find many families, genera, and so on, with an assemblage of species more numerous than all the other classes put together. Next we have the Tooth Shells, containing the Class *Scaphopoda* alone. Following these we have the Bivalves containing the Class *Pelagicypoda*, and finally there are the Cephalopoda, created to contain the Argonaut, the Chambered Nautilus, the Squids, Sepias, Spirula, Octopi, and the Many-armed Mollusks.

Of this enormous host it will obviously be impossible to describe here but a few representative shells scattered through the various genera or families; for, were only a single species of each genus briefly described, the result would be the production of a very extensive volume.

When we come to view the univalve shells as a whole, collected in all parts of the world where they occur in nature, we very soon recognize the fact that the group long known as the Murex shells is by far the most interesting as well as the most numerous, with respect to the number of species it contains. They have been arrayed in the family *Murididae* which, upon division, is seen to contain two subfamilies, the *Muricinae* and the *Purpurinae*. In the first, the shell develops on its external surfaces more or fewer remarkable projections termed *varices*, and the *nucleus* is located near the center of the operculum. Upon the other hand, this latter is close to the margin of that structure, and the



A fine collection of shells from the National Museum and the author's private accumulation. For details see the text.

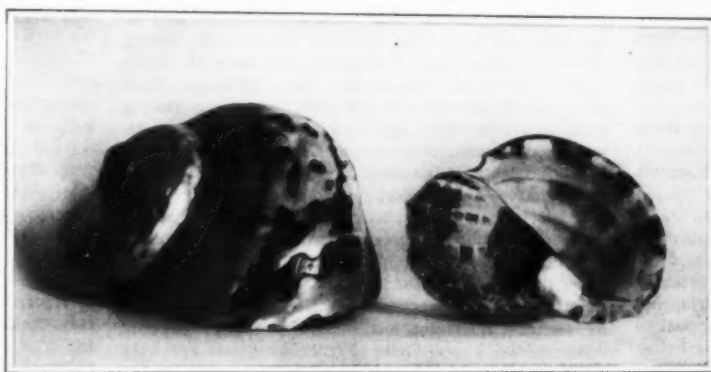
ornamental projections on the shell are reduced to mere blunt *nodules*. Still other characters differentiate the *Muricinae*, and we further discover that the genus *Murex* of the subfamily *Muricinae* contains over 250 of the most extraordinary and grotesque-appearing shells in the world.

Anyone possessing the slightest knowledge of shells is familiar with the beautiful "Comb of Venus," with its delicate and conspicuous spines,—the Woodcock Murex and the "Snipe's Head" being almost as well known. Less striking specimens are the branched Murex, the rose-branch Murex and Stamford's Murex, all of which are illustrated. Most of the representa-

snail of large size. Its curious "egg-ribbons" are to be found in many places along this shore line, and to many of the great body of the uninformed they still offer a very puzzling structure; generally they are taken to be "some kind of sea-weed."

Linnaeus made another species of the "Left-handed Whelk or Lightning Shell," which Rogers says does not occur except on our Floridan coasts. However, the one here shown was collected on Smith's Island, which is as far north as the mouth of the Potomac River. It may come to be 12 or 13 inches long, and the young are marked with zigzag lines or lightning streaks radiating from the spire. One of the most interesting chapters in conchology is the study of the Knobbed Whelk and its breeding habits. It is one of the most dangerous enemies of the oyster, drilling a small, clean-cut hole through the shell of their victim, and through this sucking out the soft parts of the bivalve. The Channeled Whelk (*Fulgar canaliculatus*) is another form, occurring from Cape Cod to Texas. Then we have the typical Whelks (*Buccinum*), the Ivory Shells (*Eburna*), and all the numerous whelks belonging to the family *Nassidae*, which includes the Dog Whelks and Basket Shells, not to mention the Chank Shells (*Turbinellidae*).

Another widely known and greatly admired group of shells are the Volutes and Melons of the family *Volutidae*. Many collectors have devoted themselves entirely to the first-named (*Voluta*, *Lyra*), the Melon shells being confined to two small genera (*Melo* and *Cymbium*) together they constitute a carnivorous family, living in the deep waters of the tropical and subtropical seas, mostly in the Southern Hemisphere. Many of the volutes are very beautifully marked and the species are quite numerous. Some of the chief species are the Imperial Volute (*V. imperialis*), the Music Volute (*V. musica*), the Magnificent of East Australia (*V. magnifica*), the Waved (*V. undulata*), the Flag (*V. vexillum*), and some five or six others of note. In 1840, M. Duchant-Cilly described the eggs of these shells and their development, his observations being made on forms seen in the Straits of Magellan. Most of the volutes are found



Left lateral aspect of West Indian Top shell (*Livona pica*); Swollen Harp Shell (*Harpa ventricosa*)

tives of this subfamily, if not all, inhabit the shores of both hemispheres in the subtropical and tropical regions. Some are found in relatively shallow waters near the coastline; others live at depths varying from a few to three hundred or more feet. Many species of *Murex* are elegantly colored, their interiors being very smooth and enamel-lined. Often they are unusually solid structures, large and heavy; while in the matter of their growth and development, they present numerous peculiarities. Rare species fetch high prices in the markets, while they are otherwise of commercial value to the cameo-cutters.

Both *Murex* and *Purpura* furnish the secretion from which the "Tyrian purple" is obtained—or at least it

in the waters of Australia, and some of the species there are most extraordinary both in form and color.

In another figure we have the left lateral view of the "Shell" of the Argonaut or Paper Nautilus (*Argo argonauta*, Linn), one of the Cephalopod Mollusks. These are usually divided into two orders, the group as a whole containing some of the most remarkable animals known to us. What has been written and published about them would form a fair-sized library; and so extraordinary is the life-history of any one of the species, that it would require a separate article, with appropriate illustrations, to do the subject justice. Four hundred years before Christ, Aristotle wrote of this creature, the egg-carrier of which is here shown.

Some marvelous shells of great beauty are found in the univalve family *Trochidae*, created to contain the Top and Dolphin species. *Livona* is the genus containing some of the handsomest of the Top shells, and no one of them is more elegant in form and color than the West Indian Top Shell (*Livona pica*, Linn.), a fine specimen of which is here shown. When I was a young officer aboard one of the U. S. gunboats in the East Gulf Squadron in 1864-65, that shell could be purchased for a trifle in any of the shell shops in the then modest coast town of Key West. It would seem that it could still be found as far north as Charlotte Harbor on the West Coast, while further south, in tropical waters, the form is very abundant in some localities. So beautiful is the shell of this *Livona* that many of them are gathered and sold for various purposes in the trades and arts. The specimen shown is rather above a medium sized one, being not more than three inches in height, whereas those of over four inches have been found. It has been cleaned by an expert, so that its wonderful coloration has been brought out to the best advantage. Its ground color is a rich pearl, exhibiting the most beautiful reflections in various lights of green and other shades. This rich body-color is off-set by wavy bands, dots, and irregular markings of a highly polished black. Part of the surface around the aperture and between the whorls is of a rich chestnut. The terminal whorl and apex is of a deep orange, preceded by a rich yellow which joins with the chestnut. Julia Rogers says of this shell that "It lives in great numbers on the rocks and coral reefs, near shore, where it may be seen through the limpid water crawling along, waving two long tentacles ahead and a fringe of cirri almost as long on each side of the foot. When the surprised tourist sees one of these large top shells climbing a tree (a very common sight in the islands), he may be sure that the mollusk is dead and its vacated shell is inhabited by a hermit crab."

It is truly a remarkable fact that so many hundreds upon hundreds of gorgeously colored shells all over the world are, in nature, completely covered over by some sort of limy deposit that entirely hides every particle of the coloration; it is not until man skillfully cleans it off and laboriously polishes the specimen that the marvelous splendor of most of them is apparent.

Passing to the family *Olividae* containing the remarkable Olive, Rice, and Harp Shells (*Harpa*), a few words may be devoted to the last-named and the beautiful forms it contains. (*Harpa ventricosa*, illustrated.) Conchologists usually array some nine species in this genus, none of which are found in the Atlantic Ocean; on the other hand they occur in all tropical seas. If we select *Harpa ventricosa* or the Ventricose Harp as an example, and hold it so it may be viewed with the back of the shell toward us, it strongly suggests the outline of a harp, with the raised parallel ribs in line from spire to base, standing for the strings. This fancied resemblance has come down through the ages, and the various generic names bestowed upon these lovely and delicately tinted forms have in all instances carried out the idea, as *Lyra*, *Harpalis*, *Harparia*, and so on. With so much to attract the eye and appeal to the sense of beauty, these harp shells have for all time been universal favorites among shell collectors, and a complete collection of them is surely worthy of all the study and admiration we can bestow upon it. The animal that inhabits the *H. ventricosa* has been studied with considerable care and with most excellent results. Its parts are highly colored, rivaling the very tints and shades of the shell itself.

We may now pass to brief descriptions of some of the shells here reproduced from my photographs in a large group. Most of these are from the superb collection in the United States National Museum at Washington, and in the matter of selecting them I am indebted to Dr. Paul Bartsch, the curator, and to his assistants, Mr. Marshall and Miss Boone. The three specimens at the bottom are from my private collection.

In the two upper corners we have the back and front views of the far-famed Precious Wentletrap (*Scala pretiosa*, natural size); it belongs to the family

Scalidae containing these Wentletraps, the Ladder, and the Staircase Shells. There are a number of species in the group, and they occur principally in the West Indies, though the specimen here shown came from China. All the wentletraps, when irritated, eject a peculiar, purplish fluid, and to this the *pretiosa* forms no exception. No shell known to me possesses a more extraordinary history with respect to its relation to man than this species. At one time naturalists thought it was only to be found in Chinese waters, but since then its known range has been extended to certain of the Australian coasts. Nearly two and a quarter centuries ago these shells were considered such rarities in collections that many a fine specimen fetched forty guineas each, or about two hundred dollars, in the London and other markets. Few specimens exceeded two inches in length, and they were of a glistening white from apex to aperture. Note the peculiar raised flanges on the whorls; they give the shell a very attractive appearance. At one time, when the exorbitant prices for them prevailed, the Chinese made the shells of rice flour, deceiving many a purchaser with the faked ones. We can now buy pretty specimens of this species for a dollar or so, and surely they are worth that in any collection. A popular writer on shells of the early part of the last century says: "Some of the Wentle-Trap shells are of great value. The Royal Stair-case Wentle-Trap, *S. pretiosa*, found in China and Indian seas, formerly sold for four hundred dollars; a fine specimen is even now worth twenty to thirty dollars (1861). On account of its value, Lamarck gave this species the specific name of *pretiosa*, that is, valuable or precious." There are a number of high-priced shells to-day, and I have photographed those that cost fully as much as did a fine specimen of *S. pretiosa* in 1700. Upon the whole, the species of shells making up the genus *Scala* are a wonderful assemblage of dainty forms.

Curious shells are the Worm Shells of the family *Vermetidae*, and a fine specimen of our Floridan species (*Vermetus radialis*) is figured between the two Wentletraps. No two specimens of this curious mollusk are ever alike, for the spire takes on a different twist in every individual. This is not quite true of the young, as in the very early stages the spire or whorls are regular in their twist, while in the adults the distal portion turns about in various ways. We often find small ones in sponges, and they are abundant on the coral rocks along the Gulf coast of Florida. In color they are gray or of various shades of light brown, with no special markings—often almost a dirty white. Some specimens attain a length of ten inches, and they form curious additions to the conchologist's collection. Occasionally they come together in masses, apparently for the purpose of protection, though it is hard to say why it is demanded. Generally they are found in rather shallow water.

A few years ago some of the scientists of Washington gave a dinner to the veteran naturalist of the Smithsonian—indeed, one of America's best known and most distinguished naturalists—Dr. William Healy Dall, who has, for considerably more than half a century, been a steady worker and contributor in the field of general conchology. An elaborate menu was prepared for this banquet, the cards each having at their heads a picture of a new species of a large Philippine land snail, which Doctor Bartsch had named for Doctor Dall, *Prodallia dalli* and which had never been described or figured before—nor has it been up to the present writing. This shell is a handsome univalve of a deep olive brown color, and very glossy. The type specimen was photographed by me and is here reproduced, appearing just below the Worm Shell described in the previous paragraph. It is its first appearance since the cut decorated the famous Dall menu card. At either side of it appear views of *Murex stanforthi*, Reeve, from Australia, mentioned above.

Among the Auger Shells (*Terebridae*, genus *Terebra*) we have some beautiful species, such as the *Terebra dimidiata* of the Society Islands, a fine specimen of which is seen to the left of the mussel. There are upwards of 175 species of these, the form in the cut being one of the handsomest of the group, its orange and buffy-brown tints making it very conspicuous in a collection. Some twenty-five fossil Auger Shells have been described, the existing forms being almost entirely confined to the warm seas of the tropics, and not often out of shallow water; those that occur on our coasts (*T. dislocata*, etc.), are small and plainly colored. Mark the fine, tapering spire carried almost to a needle point of this remarkable univalve. At the other side of the group is seen an interesting univalve of similar construction from Tongatabu, known as *Fusus colus*.

The Mussel shown next to the Auger Shell is an elegant specimen of the Plaited Horse Mussel (*Modiola*

plicatula) from Cape May, New Jersey. It ranges from Nova Scotia to Georgia, *M. tulipa* being found from North Carolina to the West Indies, while the species on the Pacific coast is the Straight Horse Mussel (*M. recta*). Mussels belong to the family *Mytilidae*, a very extensive group of bivalves which cut a very important figure in nature; most of the genera are represented in the United States. Thousands upon thousands of them are often massed together in a locality favorable to their existence. In some places myriads of them attach themselves to piers of wharves or to submerged branches of trees and driftwood. This is done by means of the *bysal threads* which the animal can spin, and some species use this peculiar animal thread to hold sand and bits of shell together to form their nests. Indeed, mussel history is a long story, and an account of the Edible Mussel (*M. edulis*) of Europe is a big chapter of itself. Many mussels are used for bait—in fact tons of them are used in this way every year. The structure of the animal—the mollusk—found in this bivalve is most interesting and instructive.

Many years ago, when I was living on Long Island Sound (New England), there was a large trade in mussels, they being purchased by the farmers for purposes of fertilization. The life-history of a common mussel would afford ample material for a volume of such size as Huxley's "Cray-fish".

Upwards of 200 species of Cowries (*Cypridae*) are known to science, with nearly half that number of fossil forms. Their convoluted shells are elegantly enameled and richly colored. Typical cowries all belong in the genus *Cypraea*, and a large collection of them, such as exists in the United States National Museum, is truly a wonderful sight. Their variation seems to be almost infinite, and more will be given about them in Part II. of this contribution. The only species figured here are the two little shells immediately below the *Prodallia*; these are specimens of the Money Cowry (*C. moneta*), the one on the left being pure white, while the smaller one is a Naples yellow on the back. They are as glossy as china and quite as smooth. These truly historical shells occur in enormous numbers in Australia, and throughout the Pacific Islands and those of the Indian Ocean. For a long time they have been used as money by the natives on the western coast of Africa, and consequently they have, along such lines, a most interesting history, dating back as it does far into antiquity—a thousand years or more. Only the perfect shells are of any value,—that is, those having the gloss and perfect form. An early writer at hand says that they "are collected in immense quantities by the British, and taken to Africa to be disposed of to the negroes. In 1849 three hundred tons of these were imported into Liverpool for this purpose."

W. Saville-Kent, F. Z. S., tells us that "It is recorded that as large a quantity as sixty tons of these small shells, originally collected from tropical seas, have been shipped from one British port alone to the African coast for commercial use within a single year." It takes 60,000 cowries to make a dollar, and 100,000 cowries to buy a young wife; even a much older and very ordinary wife will cost 20,000 cowries,—or about six dollars or twenty-five shillings.

A most remarkable as well as beautiful family of bivalve shells are assembled in the *Veneridae*, known among conchologists as the Venus Clams; three specimens of these are shown beside and below the money cowries just described, and they were photographed from different points of view in order to exhibit all of their peculiarities and characters. All these specimens belong to the species known as *Dione dione*, and were collected at Nicaragua, north coast of South America and Trinidad. Most of the finest species center in Australia and the Eastern Seas, and the species known as the Orange Dione is especially handsome (*C. aurantia*), its highly polished and very smooth surface being of a fine orange tint. So well are the characters of these shells shown in my reproduced photographs, that no special description need be given. The remarkable spines are nearly always broken off in cabinet specimens, and this greatly mars their otherwise attractive contours.

The big Moon Shell in the middle of the lower row is from Australia and has already been referred to. At its left we have the ventral view of a species of *Cassia*, probably *C. testiculus*, one of the smaller Helmet Shells, while the one to the right is one of the common Top Shells of the genus *Chlorostoma*, and probably related to *C. annulata*—if that be not actually the species. It is an imperfect specimen of my own. The majority of the species of *Calliostoma* inhabit the Pacific coast of the United States, while the one found on the Atlantic coast of Florida and the Carolina is *C. euglyptum*.

The Motor Fuel Problem*

EXPERTS in different industrial branches would, on inquiry, probably draw up different lists of key industries. None of them, however, would omit to class the industry of internal-combustion motors among the most important key industries, and this not only because these vehicles are still wanted in the Army. The war has so thoroughly changed all industrial foundations—quite apart from political and national considerations—that it will for some time to come be difficult to dismiss it from our minds when estimating the future. What was necessary, possible and probable during the war, may become undesirable and impossible in normal times. Some of the special uses of motors, uses which have rendered their rapid perfection possible, may vanish. But the motor will conquer other fields in which it had before the war already obtained a firmer footing in other countries than over here. Authoritative statistics are not available at present. To characterize, however, the importance of the industry, Mr. W. R. Ormandy, D.Sc., when discoursing on the Motor Fuel Problem before the Institution of Petroleum Technologists recently, stated that he estimated the wages paid annually in this country for the manufacture of motor vehicles at more than 10,000,000. That estimate entirely disregards accessory industries connected with light alloys, springs, rubber, tires, leather, &c., some of which may almost be said to stand and fall with the motor as matters are now. The United States are credited with 5,500,000 motor vehicles, half of which serve for farming, forestry, mining, stock raising, fisheries, &c. Motor transport and agricultural developments are inseparably linked. In the future aeroplanes will need much motor fuel. A Handley-Page machine alone consumes as much as 40 motor cars per hour, Dr. Ormandy believes, and even without the war the country would have wanted 200,000,000 gallons of motor spirit per annum by this time. Where is the fuel to come from?

America produces some two-thirds of the world's petrol from natural oil; but it has long felt the pinch, and though new petroleum fields are opened, old ones dry up, and an actual world shortage will have to be met sooner or later. What other fuels can be utilized in internal-combustion engines? Dr. Ormandy distinguished them as solid, gaseous, liquid. Solid coal can be gasified in the producer, but bituminous coal is hardly suitable for such purposes. The last word has not been said regarding steam-driven motors, however; the Clarkson motor omnibus has so far been run on paraffin, but Mr. Clarkson has, according to Mr. Ormandy, obtained promising results with coke-fired boilers. As regards charcoal, the woody lignites of Ireland may give a suitable fuel for producers. But though solid fuels may be adapted to serve as indirect fuel for stationary engines and heavy portable motors, they cannot play an important part. That gaseous fuel, compressed town gas, can be burnt in motors, has been shown; 250 cub. ft. of gas are considered equivalent to a gallon of petrol; the introduction of suitable containers would render another auxiliary source available; but it would not do more.

The more important liquid fuels are petrols, paraffin oils for marine engines, &c., and fuel oils for Diesel or semi-Diesel engines. Substitutes for petrol are gained by coal distillation. By-product ovens yield from 1½ gallons to 3½ gallons of liquid fuel per ton of coal carbonized. From the gas of gas works similarly 1 gallon or 2 gallons of benzol and toluol are obtained, and post-war conditions, Mr. Ormandy suggested, might yield some 50,000,000 gallons per annum. If central electric power stations should take the expected development in combination with producer-gas plants, however, that figure would be smaller. Shale oils help also, and the sulphurous shale deposits from Norfolk down to Dorset might be utilized; but that again would be a minor factor. The next available source, alcohol, could certainly be produced in almost unlimited quantities; but the heat of combustion of alcohol was relatively low, alcohol was not readily inflammable, and the advocates of alcohol-fuel had prejudiced their own cause. In any case little had been done by the public, the motor users, to whom motor manufacturers left that problem, and the Government had been guided by the experts of the Excise Department. Alcohol could, and was, produced in the first instance from sugar molasses by fermentation, and there was no reason why sugar beet crops should not thrive here. If grain-raising were to be pushed, in fact, roots would have to be planted in rotation, and sugar-beet root might profitably replace turnips and mangolds; Dr. Ormandy seemed to forget that sugar-beet roots require heavy manuring. Sugar-alco-

hol, however, cannot directly supply the Empire's motor fuel, even if local industries, like the sugar manufacture from the Indian mowrah-tree flower, were fostered.

But there are indirect sources of sugar. By digestion with alkalis or acids both starch and cellulose are converted into fermentable sugars. The English glucose is mostly starch-sugar, and quite an important article as such. The most common source of starch is the potato. In Germany, Dr. Ormandy rightly pointed out, alcohol is not produced from potatoes because they form the cheapest raw material available, but because their use favors home agriculture. Hundreds of square miles of sandy soil, notably in the eastern part of Prussia, sustain an agricultural population, which is occupied in the fields in summer, is busy in the distilleries in the winter, and obtains a valuable cattle food in the distillery residue (schlempe). The special potatoes for the distillery fetch about 22s. per ton in Germany; that money, however, would not alone keep the people, if it were not for the work and other profits drawn from an agriculturally poor soil. The Prussian Government has wisely encouraged potato farms and local distilleries which are the joint property of small peasants or owned by the great landlords. The question, however, is not really capable of such brief summation as Dr. Ormandy attempted. He did not overstate his case, however, and he warned his hearers against the optimistic estimate which Mr. R. W. Tweedy had given in a pamphlet on industrial alcohol. The alcohol yield of the best special potatoes does not exceed 20 gallons or 25 gallons of 95 per cent. alcohol per ton of potatoes, and Ireland could not produce 150,000,000 gallons of alcohol from 2,500,000 tons of potatoes, certainly not if the potatoes were to be sold at 3l. 10s. per ton to the distillery. For warmer climates, in Australia and Africa, maize yielding 75 gallons of alcohol is a much more promising material, of course.

Successful experiments on the conversion of cellulose into sugar by the Classen process have recently been made in the United States, on a large scale, Dr. Ormandy mentioned; but he did not give particulars, except that he spoke of a yield of 30 gallons or 40 gallons of commercial alcohol per ton of wood. How these figures compare with the 10 per cent. of 95 per cent. alcohol which the Ewen-Tomlinson process is said to yield, we do not know. The difficulties lie mainly in the construction of suitable vessels not attacked by hot acids under pressure. The sulphite wood-pulp residue treatment seems, however, really to have risen from the experimental stage, if Sweden has works producing 4,000,000 gallons of alcohol per annum in operation, and works for 3,000,000 gallons under construction; Norway is credited by Dr. Ormandy with works for 4,000,000 gallons, the strength of the alcohol not being stated. Sulphite wood pulp is the residue from paper-making with calcium or magnesium sulphite (instead of the more expensive caustic soda). The logs are sliced at right angles to the fibre and boiled for 5 hours or so at 2 atmospheres pressure in vessels lined with lead; the sulphite is prepared in Glover towers or in vats. The sulphite liquor has so far practically been a waste product; there are difficulties about neutralization to start with, and it would be interesting to know how alcohol is obtained from the liquor, though it generally contains some sugar. There is finally the synthetic production of alcohol, from calcium carbide *via* acetylene. Such processes are certainly worked in Germany and by the Lonza Company in Switzerland, as we noted some time ago; with what results is not yet known.

With the question of the suitability of alcohol as motor fuel we have dealt on other occasions. Thousands of alcohol motors, chiefly stationary for agricultural purposes, engines working with long stroke and high compression and fitted with pre-heaters for starting, were working on the Continent before the war. The higher thermal efficiency of these alcohol motors balances the lower heat value of the fuel, and the much-dreaded corrosion of the cylinders can be averted, as Continental experience and the experiments carried out by the *Auto-car* prove. That alcohol can also be used as fuel mixed with benzol, in the ratio of 2:1, *e.g.*, without calling for more alteration of the engine than required for pre-heating the air supply and slightly enlarging the jet, is likewise established; motors run more smoothly on such mixtures than on petrol according to Dr. Ormandy. There is, of course, need for further research, as to viscosity, vapour tension, the admissible percentage of water, and the best proportions of mixtures of benzol, alcohol and water, and also alcohol-benzol-ether mixtures. Lubrication problems may also arise. The use of paraffin oil mixed with petroleum caused trouble in the bear-

ings, and Dr. Ormandy found out in experimenting together with Mr. Lester that, when petrol is used, a certain amount of this fuel gets into the crank-case oil and sets up an equilibrium depending upon the temperature of the oil, the amount of ventilation and other factors. Moreover, with paraffin, which has a lower vapor pressure, larger quantities are washed out and retained by the oil spray in the crank-case, so that the viscosity of the lubricating oil is diminished.

The main questions are, however, how the supply and the distribution of an alcohol-benzol mixture, in the ratio 2:1, can be secured and maintained. These are largely financial questions, which Dr. Ormandy argues on the following lines. The United States are supposed to have built 1,700,000 motor vehicles (not including motor ploughs, boats, aeroplanes, petrol-driven lighting and pumping sets) during the past twelve months. At the rate of 400 gallons annually these motors would alone consume some 700,000,000 gallons or 2,000,000 tons of petrol; supposing crude petroleum to yield 20 per cent. of petrol, an additional 10,000,000 tons of crude oil would be required to keep the American cars of one year on the road. The world's production of petroleum probably does not exceed 50,000,000 tons per year. The present production of benzol for motors in this country may come up to 50,000,000 gallons per annum; if 100,000,000 gallons of alcohol were also available, the present demand could be met. To double the benzol output of petrol, as we shall see, necessitates that the output of the gas works and the iron and steel trade should be doubled, and the enormous capital involved in these expansions cannot be got into operation as rapidly as the fuel demand is increasing. There is hence no alternative in sight except alcohol. This demand for alcohol is no new fancy, of course. The report of the Imperial Motor Transport Conference of 1913 may be summed up in the words "Develop alcohol fuel," and Dr. Ormandy himself had advocated alcohol in the Automobile Club twenty years ago when petrol was 1s per gallon. An Inter-Departmental Government Committee, of which Sir Boverton Redwood is chairman, is dealing with fuel-alcohol.

We pass to the distribution problem and the gas and iron works. The production of benzol depends upon gas works and coke-oven works. The gas works will grow, and hence be able to produce more benzol; but they will also have to utilize low-grade coal, and to face many new problems. Dr. Ormandy, we might interpose, seems to presume that the gas companies are willing to go on with stripping the gas; some gas engineers certainly wish to be relieved of this obligation. Coke ovens, the other source of benzol, can only grow together with iron and steel works, and whether they will put down benzol-recovery plant will depend upon the market value of the benzol. To control the market the petroleum companies will endeavor to obtain possession of the benzol supply. They can rightly claim that they are able to mix the benzol with the petrol and that they possess the organization necessary for distributing the product. The benzol producers, likewise organized, might dispose of their whole production to the petroleum firms at an agreed price, or on a sliding scale, to be relieved of the distribution worry; but they cannot expect to control the motor fuel market if they supply only part of the total demand. The petroleum companies hold the field apart from the benzol; they are corporate bodies existing for the purpose of making profits. They can also retard the progress of alcohol. Thus the fuel users, the public, will be shorn, unless the Government step in, or the users combine with the motor industry to secure the benzol supply of the country as a national asset. They will combine, Dr. Ormandy thinks, if they recognize the situation.

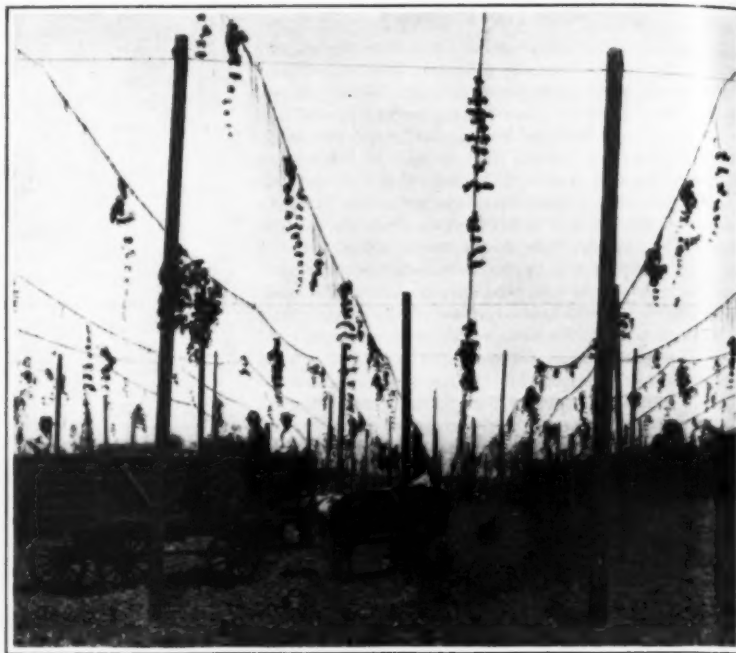
Electric Melting of Brass

IN the *J. du Four Electrique* some notes on electric brass furnaces are given, the advantages of which are summarized as follows: Hand labor a minimum, because the capacity can be raised to 3-4 tons and the application of the heat does not involve manual labor; no crucible and maintenance running costs, except the renewal of electrodes which requires determination by long experience; loss in zinc probably little different from that in small covered crucibles as the furnace is a closed one; insignificant oxidation; no dross requiring treatment. It is convenient that if combustibles are replaced by electric power, the furnace will require about the same number of kilowatts per 100 kg. of metal turned out as the kilograms of coke consumed by the ordinary furnace for the same output. Theoretically, the electric furnace is ideal but its development depends on low price of energy.—*Jour. Ind. and Eng. Chem.*

*From *Engineering*.



Labor trouble on the hop ranch



A hop field when picking is almost completed

Growing Hops in California

A Glimpse at an Industry That Will be Hit by Prohibition

By Arthur L. Dahl

THE gates of Prohibition have already swung closed upon the breweries of this country and the making of beer and ale commercially is a thing of the past. In the very nature of things a very large proportion of the investment represented by the breweries will be lost, as much of the machinery and equipment was especially designed for that purpose and where the plants are converted into other lines of industry the special machines must be scrapped. Aside from the manufacturing plants, Prohibition is going to hit, and hit hard, a branch of our agricultural industry which is dependent entirely upon the continuance of breweries. The growing of hops in the United States represented, in normal times, an industry running into the millions, for almost 50,000 acres of land were devoted to their growth, with an annual production of from 50 to 60 million pounds of dry hops, valued at nine or ten million dollars. With their ordinary markets closed, the growers of hops will have to stop their production unless new markets outside this country can be developed. At the present time, due to war conditions, the export demand for hops is greater than the supply, and American hop growers are receiving top prices for their goods, with every indication that this demand will continue for at least another year or so. In the big hop districts of California and Oregon hops will continue to be grown during the season of 1919 and possibly longer, dependent upon the continuation of the foreign demand. When the hop growers of Germany and Austria attempt to regain the old trade they enjoyed with South American and Oriental countries, the American growers will have to meet the fiercest competition, and whether they can retain the trade that now comes to them voluntarily remains to be seen. The American hops grown on the Pacific Coast are said to be fully equal to the European product, but the cost of production is higher in the United States.

When the war ended and shipping was released for commercial purposes, buying orders for American hops came in a veritable flood from all parts of the world. England, always a large user of hops found her supplies exhausted, and orders were placed on the Pacific Coast for fully half the total production. In addition large orders were received from Sweden and Norway, from India and South Africa, and from virtu-

ally all of the Central and South American countries. As a result of small ads carried in foreign trade papers, one California hop dealer reported having received cable orders for almost a hundred thousand dollars worth of hops from a brewery in India, and similar experiences were had with other distant parts of the world. Until the war closed the English market to this firm shutting off a natural outlet for thousands of bales of hops each year, no effort had been made to develop new markets. But the same conditions that prevented American hops from going to England prevented German and Austrian hops from supplying their regular trade in many foreign countries, and this demand was turned to the United States. The scarcity of ships and inability to make deliveries seriously

hampered the American exporters, and the reserve stocks of hops outside of America were largely used up. Now with the loosening of transportation, this foreign trade is coming to America eating up all stocks on hand and assuring a market for this year's crop at fancy prices. While a number of the small growers have already converted their lands to other uses, the big growers are not only planting their usual acreage but in some instances increasing it to meet the foreign demand.

As the successful growing of hops requires a fairly good type of soil, there will be little loss in the utilization of the hop lands of the West, for other crops of known value can be substituted. When it comes to utilizing the hop drying plants, however, of which there are several thousand on the Pacific Coast, it will be difficult to find uses for all of them. During the period of the war one of the largest hop growers turned a number of his hop kilns into vegetable driers and secured big contracts for dehydrated vegetables for use of the American army abroad. With the return to normal times, however the demand for these dried products will warrant the operation of but a few driers, unless a large advertising campaign is carried on to educate the public to the merits of dehydrated food.

Experiments conducted in hop driers have shown that all kinds of berries and fruits can be dried quickly and satisfactorily therein, and if the volume of fresh fruit is sufficient to operate the plants for a fairly long season, the cost of drying is comparatively low. Experiments in the drying of various kinds of salt-water fish shipped from points along the Pacific Ocean also disclosed that fish can be successfully dried in hop plants. Apples are produced in vast quantities on the Coast, and in many cases the hop kilns could be converted into apple driers. Co-operative associations for the marketing of specific lines of food products have reached their highest state of development in California, and the cantaloupes, raisins, oranges, prunes and other fruits raised in the Golden State have been successfully introduced into all parts of this country and to many foreign lands and an immense business developed by the associated growers who centered upon a single brand or two, advertised as a unit, and established a marketing organization in all important buying centers. With such



A hop picking camp in California



Hauling hops to the kilns

an organization, made up largely of the big hop growers, it would be possible to create a new industry, putting upon the market certain kinds of dried berries, or fruit or fish that would utilize the many hop driers now stretching from British Columbia to Central California.

The growing of hops has always been more or less of a specialized industry, with certain distinct problems to solve such as that of labor. The planting and harvesting of the crop could easily be handled by small crews of men, but the harvest season called for a great deal of labor at a time when competition was the keenest. Hops ripen, on the Pacific Coast, late in the summer and early fall, and the season of harvest is a comparatively short one. As the vines grow to great heights, and spread out over the system of overhead wires and poles arranged for them, the volume of hops to be picked is very great. In their green state when picked, the hops contain from 65 to 75 per cent. of water, and this moisture quickly ferments unless the hops are cured shortly after picking. As the hops in a certain district all ripen about the same time, the demand for pickers is very keen and the experienced workers are capable of making excellent wages, and there has grown up a nomadic army that travels from one hop district to another, from British Columbia, through Washington and Oregon into California. These hop pickers are not always the most peaceful citizens, being made up of many nationalities, creeds and political beliefs. Some serious riots have occurred in the hop districts, requiring the calling out of the State Militia to restore quiet. These pickers usually live like gypsies, cooking their meals in the open, sleeping in tents, and often whole families will engage in the work moving from place to place with the season.

Hops, to produce the best flavor in beer, should be harvested and dried when fully mature, but on account of the difficulty of getting pickers at such a time, many growers start picking as soon as their hops begin to turn yellow and continue the drying process long after the hops should have been picked. A great deal of the quality of hops depends upon the skill in curing them, so that it often happens that early-picked hops, when carefully cured, will look and be better than hops picked at the proper time but badly cured.

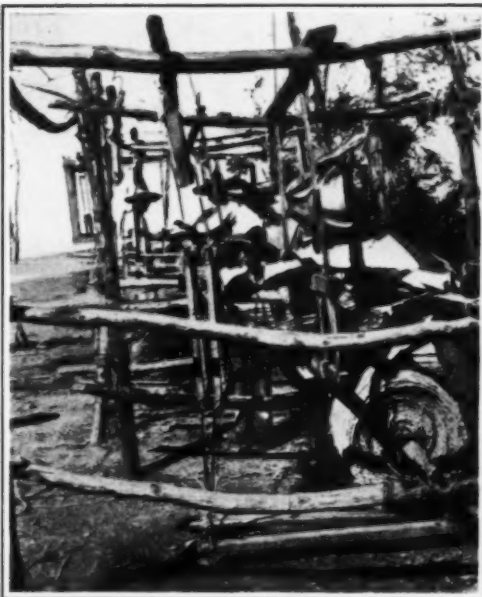
The hop kilns used vary greatly in construction and operation, but all are designed to extract the moisture in the hops. Practically all of them have curing chambers in which the hops are piled, to a greater or less depth, and underneath this chamber is a heating arrangement which forces hot air through the mass of hops until they are cured. In the larger plants, the method of distributing the warm air is so regulated that all portions of the drying chamber are equally heated, insuring a uniform curing of the hops placed therein.

When hops have been sufficiently dried, they are removed to the sweating room, where they are allowed to remain piled on the floor until the remaining moisture in the berries has been uniformly distributed through the mass. Later they are compressed into bales, thoroughly wrapped in burlap and are then ready for the market. When properly prepared, hops will keep in any climate for a considerable length of time.

In the hop fields of New York and other Eastern States it is the custom to train the hop vines to climb tall poles placed in the midst of the growing fields. On the Pacific Coast, however, where the great bulk of our commercial hops are grown, a system of trellises is used. Permanent poles are placed at regular intervals throughout the fields, along which are strung heavy wires capable of sustaining considerable weight. The hops are planted from cuttings or "sets" in straight rows under these wires, and as they develop and extend their tendrils, string is used to hold them up and lead them to the overhead wires. When the wires are reached, they spread out over them, forming a solid wall 15 or 20 feet high. The poles and wires sustain the growing vines until the hops are ready for harvesting, when they are either cut down or the pickers go between the rows in high wagons picking as they go.

The Century Plant in Mexico

If we look for the century plant in our dictionary, we shall find that it is listed, not under that title, but under its somewhat more scientific name of agave. We shall find it defined and described by means of some



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Weaving hammocks and mats out of century-plant fiber

high-sounding words like amaryllidaceous, acaulescent, monocotyledonous, etc. These are not really as terrible as they seem—the first amount to little more than a surname for the agave, or at least to a statement of its immediate relationships; the second represents an effort to disguise in stately diction the fact that the century plant grows right out of the ground in a tuft of leaves, without any main stem or trunk; and the third tells us something about the formation of its seed.

But, poor practical souls that we are, all this intrigues our interest but little. We do not greatly care whether the century plant is a first cousin to the amaryllis or to the skunk-cabbage; we surely do not care what lengthy term the botanist employs to designate its physical characteristics. Indeed, if we are strictly up to date, our main interest in this or any other inoffensive vegetable is embodied in the one question, "What can we do with it?"

Our European ancestors, among whom the agave was

by the mediaeval romancers, to whom a good long interval of time had a flat and insipid flavor unless there could be attached to it some round number value. Hence the hundred years and the term "century plant."

But we poor practical mortals will insist that we have not yet had an answer to our question as to the utility of the agave. Very well, let us turn to the Mexicans and put this question; we shall get an answer fast enough. For there seems no portion of the agave structure for which the descendants of the Aztecs have not found a use. From the sap the peon makes the sort of thing that will be taboo in the United States after the first of July—nothing less than his national intoxicant, pulque and mescal. One of our pictures shows a Mexican agriculturist extracting the raw material for a hilarious occasion from the agave. Advocates of wetness need not be discouraged by the information that the agave sap is only good for this purpose when extracted from the stem of a plant that is just about to flower; for in spite of the long period that elapses before blossoming, there is no shortage in the supply of raw materials. Then an extract of the leaves is employed as a substitute for soap, to whatever extent such a substitute is required in such a traditionally soapless region as rural Mexico; and when Jose goes a-courting he shaves himself with a razor that has been stropped on a slice of the tough and withered flower-stem of the flowered and gone-to-seed century plant. Finally, the leaves of all species of agave yield a fiber which takes second place in rope making only to sisal and hemp, and which, in spite of the fact that it is not grown on any such scale as these materials, still constitutes an important element in the industrial life of our southern neighbor. It is available for the manufacture of thread and rope, and even of paper, though employed only on a primitive scale, without the aid of the machinery that has invaded and transformed the sisal industry.

The Sir Robert Hadfield Prize

SIR ROBERT A. HADFIELD, D.Sc., D.Met., F.R.S., Vice-President, has placed in the hands of the Institution of Mechanical Engineers the sum of £200, which with any income therefrom may be awarded at the discretion of the Council of the Institution as a Prize or as Prizes, for the description of a new and accurate method of determining the hardness of metals, especially of metals of a high degree of hardness.

The ordinary tests of hardness, such as are described in the Report of the Hardness Tests Research Committee (Proceedings of the Institution of Mechanical Engineers, 1916, pages 677 to 778), which should be consulted by competitors, fail to some extent when the hardness of the material exceeds about 600 to 800 Brinell. What is desired is the description of a research for or an investigation of some method of accurately determining hardness, suitable for application in metallurgical work in cases in which present methods partially fail.

The Award or Awards will be made by the Council of the Institution of Mechanical Engineers, whose decision will be in all cases final.

The Council will consider annually all communications received, and may then award a Prize or Prizes. But in January, 1922, the offer of prizes will be withdrawn, and any unexpended balance of the Prize Fund will be diverted to any other purposes to be determined at the discretion of the Council.

The Council may award the whole or any part of the sum available at any time if a communication is received which, in their opinion, is of sufficient originality and importance and satisfies the object aimed at; or they may from time to time award portions of the Fund, not exceeding in all £75 in any one year, for communications which do not completely solve the problem, but which appear to advance the knowledge of methods of testing hardness.

The Institution will probably be willing and reserve the right to publish in its Journal any communications for which a prize is awarded.

A communication should be accompanied by scale drawings of any new apparatus described, or by a model or an example of the apparatus itself. If the communication describes a new invention, likely to be of commercial value, it is desirable that provisional protection should have been obtained before it is submitted for consideration.

Address communications to the Secretary.



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Taking sap from agave plants to be made into pulque and mescal

first introduced from Mexico back in 1561, supplied two answers to this question. They decided that they could use the agave as an ornament, and as the foundation for a pretty fable. This latter is to the effect that it flowers only after the lapse of exactly a century, and then dies. There is a modicum of truth in this; for the agave does flower only after the lapse of a good many years—from ten to fifty, or even more—and it does die after giving birth to a blossom; but the good round hundred years constitute no part of its true reproductive cycle. This period has been wished upon it

At Pompeii and St. Pierre*

The Dynamic Heating of Air as a Cause of Hot Volcanic Blasts

By George W. Cole, M.E., A.S.C.E.

PROBABLY there is no field so virgin or inviting for scientific marshaling as that part of the meteorological domain which has to do with atmospheric phenomena caused by, and following, volcanic eruption. Its ramifications reach from the vapor condensation and electrical effects of the storm to the dynamic record of the destruction of things, animate and inanimate, that fall before it. At the eruption of Mont Pelé 30,000 human beings were killed in an instant under most appalling and marvelous circumstances, yet not a single autopsy was performed and no published account can be found that assigns a sure explanation of the cause of death.

In a previous paper¹ the writer has quoted at length eminent authorities who set for themselves the question, "What causes the deaths?" and all give practically the same answer, "The hot blast, bearing sand and steam from the volcano." This is corroborated by the learned Viennese geologist, Prof. E. Suess, and by B. Koto,² of Japan, who refer to the "hot vapors and steam cloud of Mont Pelé."

It will not be the function of this paper to inquire into the ordinary smoke, vapor, and electrical effects of the eruption. They are probably of the usual nature of storm phenomena, greatly intensified by the magnitude of the action, which involves great differences in temperature, with unusual volumes of water and volcanic matter. Our task will be an inquiry into those blasts which, with swift and stifling stroke, rend, burst, blister, ignite, and upheave all that oppose them till their fury is dissipated by distance and their ardor cooled by mixture.

Volcanoes are not laboratories. They can neither be selected in advance with even approximate certainty, nor can safe stations for apparatus be chosen. After the experiment, physical and biological changes of enormous magnitude must be read in terms of analogy from our experience.

Just after the Martinique disaster it was related to the writer that bodies had been found apparently unharmed and untouched except for blisters and burns and that these blisters were under clothing, at times as frail as lace, that showed no trace of fire or scorch, nor were there contiguous evidences of fire. These people had been killed in some mysterious manner, just as the people of Pompeii and Herculaneum had been killed, stopped on the instant. The cause of death was unfathomed in the recent case, as in the earlier. We believe it was the adiabatic compression of the enveloping air, with its consequent rise in temperature, that stifled and killed, in almost a twinkling, the victims of Mont Pelé and Vesuvius, of Taal, and Sakurajima. The problem is of vital human interest.

Such heating by compression was first advanced by the writer shortly after the Martinique disaster as the explanation of the death and blisters beneath untouched lace before alluded to, but it has been the desultory work of years to assure oneself of the originality and worth of the conception and to accumulate in a small way the analogies from authentic sources and broadcast experience which would insure its acceptance.

Let us consider, first, the physiological and structural effects of the hot blasts; second, from these let us stipulate what conditions of pressure, winds, and temperatures would be necessary to produce such effects; and third, let us compare such conditions with those which occur on a smaller scale in explosions of known intensity.

The physiological, or rather pathological, effects of the hot blasts seem to be both those resulting from rise in temperature and from the rise and fall of pressure as an explosive wave passes with greater or less rapidity. Observers have reported cases of the destruction of materials varying from practical annihilation to the case of lace and fine cloths untouched, over bodies blistered and killed. Trees are cited,³ denuded of bark, with their fiber cut and shredded as by a sand blast. This is probably the manifestation of some such action as that which pops corn or puffs rice when the pressure is removed after heating and compressing the included juices or moisture. As to heat actions on man and brute, they are reported and photographed in great quantity and variety.

Mr. George Kennan reports quite extensively, among

other interesting data, the interview with one, Caparis,⁴ who was a negro town character at St. Pierre incarcerated for some minor offense. For attempting to escape the day before the disaster he was put into a deep dungeon for safekeeping and punishment. He was the only being of some 30,000 in St. Pierre who survived. Some persons doubt the existence of this negro, but my friend Walter C. Harris, with Louis Siebold, both of the New York *World*, state that while they did not see the man—they left in an hour and a half after arrival to escape the second eruption—they were given a photograph of him, of which I have a copy; and the story of him was so circumstantially told to them by different natives as to be true beyond question, and has recently been verbally confirmed to me by Mr. Lyder, who was a member of the Barbados Government relief expedition.

This man Caparis, Mr. Kennan tells us, had been burnt so deep that blood oozed from his wounds, and yet his hair was untouched, as was also the shirt covering the burns on his back. Caparis told him that he heard no explosion and smelled no odor of sulphur. He was in an underground cell with a door grated in the upper part and the air and dust came through and burned him. He heard no noise, saw no fire, and smelled nothing except what he thought was his own body burning. The water in his cell did not get hot, or at least it was not hot when he first took a drink, after the catastrophe.

In the Philosophical Transactions of the Royal Society of London (vol. 200 A, 1903) Drs. T. Anderson and J. S. Fleet in their article "On the eruptions of the Soufrière and on a visit to Montagne Pelée in 1902," pages 353-553 and plates, give much valuable information and data. This supports the theory of the dynamic heat of compression, although it did not occur to them, and they cling to the older theory of black cloud, hot sand, and steam.

Their observations and statement as to the black cloud are the most minute we find, and are quite interesting. The cause of this black cloud, also alluded to by others, is not entirely clear to the writer, but may probably result from the formation of the enormous quantities of dust made by the solidification or condensation of the liquid and gaseous material which exploded violently on the release of pressure when ejected from the crater. It may also be that the high density of the atmosphere as it comes under compression would so vary its refraction, especially with its undoubtedly disturbed surface, as to cause it to become nontransparent and dark. Another factor in the production of the black cloud must be the dust blown up from the surface by the tremendous wind.

Their report notes in one instance sufficient heat in ashes to scorch a negro's skin but not for two hatfuls of the same hot ashes to singe his hair. Their records of pages 396-398 strongly illustrate experiences on the outskirts of the danger zone of an eruption, especially their reference (p. 398) to the Fancy estate: "Those who escaped were badly burned mostly on the hands, the feet, and the face, but others also on parts protected by clothes, though their clothing was not scorched or ignited. The dust in the cloud was not red hot and consequently did not set anything on fire, the burns being apparently due to steam and other gases." The italics are our own.

The other extreme of burning observed after such volcanic blasts is that in which torsos of bodies burned beyond recognition with the cement of sand on them after burning are found in situations where all wood and inflammable material was likewise ignited and consumed. One case of disrupted bowels is cited in the Century Magazine for September, 1902, which may have been the result of flatulence and a sudden reduction of pressure after the pressure blast.

Destruction of material objects shows the action of a tremendous blast from the direction of the crater. Ground plans have been plotted for numerous eruptions and they show irregular, but, in a measure, concentric fields. Photographs taken of volcanically destroyed localities also show these nicely graded zones of destruction from that of utter havoc nearer the crater, to those exterior zones where whole villages are still partly standing with walls destroyed across the line of march of the pressure front, but with walls which coincided with the direction of approach of the pressure preserved. Dr. E. O. Hovey in his remarkable

photographs of St. Pierre, Martinique (*Bull. Amer. Museum of Natural Hist.*, Vol. XVI, plates), states in description of Plate XLV.: "Ruins of St. Pierre from the south—the north and south walls have been injured by the eruption less than the east and west walls." It will be noted that the crater was situated to the north of these walls. He also exhibits photographs showing trees all thrown down in a direction away from the crater.

Observations leave no doubt that there is a tremendous hot blast with a great wave of pressure emanating from the crater, generating a terrific compression with its attendant high adiabatic temperature since there is little time for dissipation of this heat. This compression of gases at the crater is accomplished by three actions:

First. The magma of the volcano approaching the outlet as a liquid, due possibly to some modification of a deep internal relegation, under heavy pressure and with intense heat is probably in the condition of the water in a boiler exploding under such intense pressure and its attendant temperature that the heat contained in the water causes the whole of the water to flash into vapor. By analogy we may possibly conceive of the ejecta of the volcano being entirely vaporized on its release to external pressure, later, on condensation, to become the sand and grit that covers the landscape. The mechanical extrusion of this vapor in itself makes the first wedge to crush the air into compression before it.

Second. The heat of this extruded matter, even after the expansion of emission, in its action on the surrounding air will cause it to expand, as the air in a back draft at a building fire, so that the expansion of the air itself will cause the air retaining it to be thrown into compression.

Third. Some of the extruded gases may be inflammable, and by their conflagration cause further heat and expansion, which will bring to bear further action compressing the outside counteracting atmosphere.

These three causes combine to give a drive and pressure to the retaining atmosphere beyond anything obtaining in other atmospheric disturbances both as to velocity and temperature.

This gives rise to destruction as complete in the outer zones of action as if done by a tornado. The velocity of the wind near the crater is incalculable, but must be of the order of more than 100 meters per second. The temperature of the gases, likewise incalculable at the crater, must range from 500° or 1,000° C., or beyond, to 200° or 300° C., where things are charred, and to over 60° C., where people were burned without their clothing having been affected. Furthermore, such temperatures must have been maintained for a time sufficient for the surfaces to get warmed to a temperature sufficient to produce the observed burns. It is a matter of common experience that only a second or two is enough for hot air to produce a burn and less than a second for steam to scald, while it may take some considerable time for a third-degree burn or worse.

Macleod, in his "Burns and their treatment," of the Oxford War Primers, gives us the discussion from which the following notes are taken: A burn is caused by a dry heat of about 140° F. (60° C.) and above; a scald by 125° F. (52° C.) and over. The degree of severity is dependent on—temperature, area exposed, and duration of exposure. The area affected is more serious than the depth of the burn. Six degrees of burns are recognized: (1) From a temperature of 140° F., redness, slight edema (effusion of serous fluid), smarting, and tenderness; (2) from 160°-210° F., marked blisters, protoplasm coagulated; (3) above 210° F., hard crust or scab is formed; (4) longer exposure to high temperatures, disintegration of skin tissues; (5) still longer cooking, with disintegration of muscles; (6) higher temperatures, carbonization. Burns involving more than one-third of the surface of the body are serious, if not fatal, and those involving one-half are almost invariably fatal. The more intense degrees of severity of burns would naturally take some time for their accomplishment and might be a measure of the duration as well as intensity of the heat involved. Mucous membranes are also seriously affected by the inhalation of the hot vapors. As the temperatures increase, hair and eyelids, ears and nostrils will be affected. Thus from the observed effects we have a rough basis for judging the temperatures which occurred.

*Monthly Weather Review.

¹SCIENTIFIC AMERICAN SUPPLEMENT, May 25, 1918, 85: 334-336.

²Fukio Imp. Univ., Coll. of Sc. Jour., 38, 1916-17, art. 3. B. Koto, p. 71.

³Dean C. Worcester, Nat. Geogr. Mag., Apr., 1912, Taal Volcano, p. 345.

⁴Tragedy of Pelée, George Kennan, 1902, p. 74, and following.

To estimate the increase of pressure in the compressional wave, we can use (1) the strength of the blast produced; or (2) we can estimate how much increase or decrease in pressure would produce the collapse or explosion of buildings, trees or people; or (3) if we assume the high temperature to be wholly a result of adiabatic compression, we can use the estimated temperatures as a rough basis. Let us consider each. In an explosive wave it is probable that the pressure front in the destructive zone moves at a velocity greater than that of sound, or at a speed perhaps of 400 meters or more per second, varying with the actuating force, and having a destructive force inversely proportional to the distance. Thus the wind speed, no matter what the gradient, could attain a velocity of 400 meters per second were it not for viscosity and friction. The explosive effect of tornadoes seems small compared with that of the passing explosive wave with its hot blast, until its force is about dissipated. Barograph traces made at a slight distance from tornadoes have shown pressure reductions as great as 10 per cent., and it is presumed that in the tornado itself the reduction may be much greater. A release in pressure so great as this is capable of exploding buildings and probably also is able to explode bark on trees and to kill people, although it has none of the marked heat effects of the air compression. An explosive wave, however, is a study of much higher compression and its reduced pressures follow necessarily from the fact that there is the preceding compressional wave by virtue of the air from behind being thrust into that in front. The compressions we are considering are those involving some little length of time and magnitude of expression, before the action has so expanded as to be a mere wave motion. Our thesis covers the part of the field of action outside of total destruction, where heat effects are of such modified intensity and duration as to leave observable effects on material and living objects.

On man and brute in this zone the sudden rise in pressure, aside from its heat effects, must be indescribably worse on the eardrums than going through an air lock in calson work. Lung and heart action must be stifled since the ordinary maximum difference between the inside and outside of the lung wall, on strong stopped expiration, is from 60 to 100 mm. of mercury, or about one-tenth of an atmosphere. Then, depending on the length of application, in case the subject can breathe at all, is the absorption of air into the blood, with the consequent liability to "bends" on release. On the relaxation of this pressure, with its consequent relative vacuum, all the contained air in structure of plant or body becomes a bursting charge if not sufficiently secured. In animals, even if there is no explosive effect, the nitrogen will form bubbles in the blood if the pressure has been sufficiently prolonged, and in this way clog the circulation and cause death.

The pressure necessary to cause the different degrees of heat, if we assume (as is reasonable with such sudden compression) that the heating is adiabatic, or without loss of heat during compression, may be determined from the well-known gas formulas.

The relation between temperature, pressure, and volume of air at the beginning and ending of adiabatic compression (or expansion) can be deduced from Charles' and Boyles' Law.³

A general summary of these relations is shown in Table 1.

TABLE No. 1

Pressure.			Temperature.		
Pounds per square inch.		Millibars.	°F.	°C.	°A.
Absolute.	Gauge.				
5	-10	345	-80	-62	212
10	-5	690	5	-15	259
15	0	1,035	63	17	291
20	5	1,380	109	43	317
25	10	1,725	147	65	339
30	15	2,070	180	82	356
40	25	2,760	236	114	387
50	35	3,450	282	139	413
75	60	5,175	375	190	464
100	85	6,900	447	231	505
500	485	32,500	983	531	805
1,000	985	65,000	1,258	681	955

This table shows at what relatively low pressures, added to the atmospheric pressure, severe temperatures are reached. To make this more closely applicable to the conditions which probably prevailed at St. Pierre, let us assume that the original temperature was about 80° F. and the original pressure somewhat below the mean for sea-level, say 1,000 millibars (equivalent to the pressure shown by a barometer reading, 750.1 mm. or 29.53 inches).

Table 2 shows what pressures would be necessary to produce the temperatures required for burns of the first

³From Simons', Compressed Air, p. 26.

degree, of the second and third degrees, and of the sixth.

In other words, if the observed burns were due to temperatures produced by the heat from adiabatic compression, there must have been a pressure of about five atmospheres for the charring, a pressure of over two atmospheres for the severe burns, and a pressure of at least one and one-half atmospheres where there were superficial burns, provided that the pressure stated lasted for something like a second.

TABLE No. 2

[Initial temperature, 27° C., pressure, 1,000 mb.]

Pressure.		Temperature.		
Pounds per square inch.		Millibars.	°F.	°C.
Absolute.	Gauge.			
14.5	-0.5	1,000	81	27
21	6	1,430	140	60
31	26	2,120	212	100
70	55	4,900	392	200

There are many examples of this adiabatic compression of air with its resulting heat, e. g., the heating of the old bicycle pump in the hand when in use is probably the most intimate; the fire-cylinder experiment of the physical laboratory where the piston of a closed cylinder is pushed down so far and so quickly that a bit of tinder in the compressed-air chamber bursts into flames; the Diesel motor which is actuated by the explosion of oil ignited upon being sprayed into air compressed adiabatically to a very high temperature. Each detonation of a high-explosive-shell has about it the various zones of its own hot gases and the counteracting compressed hot air of a miniature eruption. So that with these and other examples it is a heat of which we have experienced various analogies and in its lighter stages is readily comprehensible. The heavier manifestations of this heat are more difficult to fathom. Mixed as they are with the equally terrific results of air motion there is good reason for there having been no previous differentiation of their coincident effects.

The observed phenomena, then, show that the hot volcanic blast is characterized by wind velocity exceeding 100 meters per second, by temperatures from above 200° C. down to 60° C. within a zone of several miles, and by a pressure wave which probably ranges from a pressure of one and one-half atmospheres to one-half an atmosphere, and which may have a pressure of more than five atmospheres.

The cause of such a blast is obviously a tremendous explosion, however undetermined, exerted upward, but conforming, in a measure, to the effective axis of the outlet, the whole process being liable to distortion, due to the barricading of crater walls and mushrooming, due to diverse air strata encountered. This explosion throws solid and liquid lava and hot gases in all directions. It sends out at a tremendous velocity a great compressional wave with an approximately spherical front. Such explosions can throw rocks more than 30 miles, and the liquid lava makes almost unbelievable quantities of volcanic dust. The hot gases are forced to not great distances. The explosive surge has an unknown change of pressure. It is obvious, however, that an explosion of such intensity as to make appreciable pressure waves encircle the earth, as at the time of the Krakatoa eruption, must produce a tremendous initial wave of compression and expansion, the initial compression being of some duration, depending on the suddenness and persistence of the source and the following rarefaction conforming to it in magnitude.

The amount of pressure will probably never be determined. In the great Krakatoa explosion an island disappeared and a boulder was hurled over 30 miles, ascending 30 miles in its flight and surpassing our usual 16-inch gun to an incalculable degree. Since the missile was fired by a flare or explosion rather than within a rifled barrel, the intensity must have been incalculably greater than that of a great gun.

Let us turn to the causes for the various grades of destruction. Those near the crater are due to the explosive action and heat of the gases as they emerge. These gases hurl and burst the material of the mountain so as to obliterate or cover it in an indescribable manner. But these gases and missiles do not of themselves necessarily range far in their travels. The wide damage seems to be done by the action of the surrounding atmosphere, through which moves the compressional action produced by the explosion.

Quoting from the second volume of Marshall's Explosives (p. 621), recently issued, we find that—

"Experiments have been carried out at various times and places to ascertain the distances at which explo-

sives will produce a specific effect according to the quantity of explosives used. In the French experiments different quantities of the various explosives were exploded in the open, and at various distances a number of little screens were erected, so arranged that the same degree of force would cause each of them to fall back. It was thus possible to ascertain the distances at which the same effects were produced. The most simple theory would lead one to expect that the distance would be proportional to the square root of the weight of the charge. These experiments, which were carried out with quantities of 0.1 to 100 kg. of melinite, 150 kg. of chedite, and 300 kg. of gunpowder were in agreement with this theory. They were confirmed by trial in which small huts with glass windows were exposed to the effects of the explosives at various distances.

"This rule is expressed by the equation $d = K \sqrt{c}$ where d is the distance, c is the weight of the explosive, and K a constant depending on the nature of the explosive and the sort of damage considered.

"For high explosives causing the breaking of window panes and slightly injuring the frames and wooden walls $K = 10$, about, the distance being measured in meters and the charges in kilograms. L'Heure also determined the velocity with which the impulse of explosives is transmitted through the air. Near the seat of the explosion the velocity is much greater than the normal velocity of sound, but it falls off rapidly and at about the distance at which window panes are no longer broken the velocity is the same as that of sound. The more brisant [sharper] the explosion the greater is the initial velocity of the impulse. Increase of the quantity of the explosive does not seem to increase the initial velocity but it causes the rate of diminution to be less.

"For small quantities of explosive the distances of equal effect are nearly proportional to the cube root of the weight of the explosive and for very large quantities the variation of the distance is more nearly proportional to the increase of the weight.

"The gases formed in powder explosions are projected to comparatively small distances. When 7,000 pounds of gunpowder exploded at Faversham, England, and the conditions were peculiarly favorable to lateral projection, the scorching effect did not extend over 50 yards, whereas serious structural damage was done at 283 yards and windows were broken at a mile."

Could not some computations be made to show the amounts of pressure change accompanying explosions of varying intensities, and to show the damping effects of the atmosphere on such compression waves? From such it might be possible to compute the initial intensity of any explosion from the distance to which the destructive effect reached.

In the volcanic eruption the question is, Do the hot crater gases actually sweep down the mountain as a withering blast effective for miles around? If not, the hot blast must be the result of compression on the front of the explosive wave. The fact of pressure disruption of trees, buildings, and even of men, and the reported compression of the air in Caparis's dungeon, and the burns under clothing indicate a pressure wave of sufficient magnitude to produce the observed heating and wind effects. A blast of hot gas would, however, also be accompanied by a pressure wave, though not so intense as the explosion wave. Since, however, in many devastated locations no gases were smelt so far as known, it seems reasonable to explain the hot blast as the result of the passage of a tremendous compressional wave travelling at a speed exceeding the velocity of sound (which is about 335 meters per second). Such a wave would kill by compression and rarefaction as well as by burning. The duration of the high pressure at any spot may be as much as a half or even a whole second or longer, depending upon the persistence of the source.

To prove this point, further observations of the intensity and duration of the explosive wave are necessary. The destructive forces in play make observations impossible. Instruments set to register and yet resist demolition, in case the time and place can be foretold, are the best that can be hoped for. These instruments should be designed to register pressure, duration, heat and if possible gather some of the atmosphere. Much ingenuity will be required in the design and making so that they will be indestructible, self-contained and yet give access for calibration and for reading and determination. As an initial suggestion, and for want of better, it is believed that pressure can best be determined by an aneroid cell of heavy metal with copper points within it, attached to either plate, arranged for indentation. Possibly the cell can be screwed together by threads in its cylindrical part, thus allowing proper setting, testing, and reading. The

(Continued on page 320)

Direct Current vs. Power Factor

A Study in Inductance and What It Means to the Engine

By Prof. F. E. Austin, Thayer School of Civil Engineering, Dartmouth College

THE universal application of electricity as a means to an end, is constantly revealing the most startling and apparently uncanny conditions. We have the use of the storage battery and motor as the starting device for automobiles, the use of a complete generating outfit on a railway car to furnish the driving power to the motors connected with the axles, and, perhaps the greatest wonder at the present time, the use of the electric drive for battleships.

Throughout the range of these various and anomalous applications, the honors of use have been shared by both direct and alternating currents. It seems somewhat notable that uses demanding small powers favor direct currents while applications demanding large amounts of power seem to favor alternating currents. The reasons for the choice of alternating currents for any specific operation may of course be logical and according to the best rules of economic practice, or they may be due to the vagaries of business, to manufacturer's proclivities, or to the fact that some particular result is desired that is entirely foreign to efficient operation.

The operation of a battleship might very truly come under the last consideration, for at times it may be imperative to achieve certain definite results regardless of financial efficiency. The question one may well raise, therefore, is whether direct or alternating currents should be employed in such applications as the operation of battleships, where there can be no question whatever that electricity should be employed. A brief analysis of the phenomena attending the use of alternating currents for power transmission, and their comparison with those attending the use of direct currents will be instructive and perhaps valuable.

The characteristic difference between direct-current power and alternating-current power, is the so-called "power factor" attending alternating-current power transmission.

As is well known, in direct-current engineering, when a pressure is applied to any device having electrical resistance, the power effect is represented by the product of the applied pressure and the direct-current it produces in the given device or apparatus. In other words in such application the product of volts by amperes gives the power delivered in watts.

If the power apparatus consists of a motor, and an alternating pressure is applied to it, the delivered power is not correctly represented by the product of volts and amperes directly; the product must be modified by multiplying it by another factor, which is called the "power factor." It is the effect of this factor or coefficient, not only on operative efficiency, but as well on facility of performance that needs consideration.

The operation of any electric power system consists of three distinctive features: generation, transmission and utilization. Since power factor attends all three in alternating current application it will be well first to consider power factor in a general way and then make specific and concrete practical applications.

Consider first a length of No. 18 gauge copper magnet-wire, 1,500 feet long. A copper wire of this size and length will have a resistance of very nearly 10 ohms. Now if this wire is laid out straight and a direct pressure of 110 volts is applied to it, as indicated in Fig. 1, a current of 11 amperes will exist in it.

If while in this same straight condition an alternating pressure is applied to the wire, an alternating current will be produced in the straight wire having exactly the same numerical value as that of the direct current. The alternating power in such a case will be exactly the same numerically as the direct-current power. But if the cotton insulated magnet wire be wound into a coil consisting of say 3,000 turns and the same alternating pressure applied to the terminals of the coil, as indicated by Fig. 2, the alternating current will now be very much less than when the wire was straight;

while the application of the direct pressure will produce exactly the same current as it did originally.

When the direct pressure is applied to the coil terminals, the applied pressure multiplied by the current it produces, represents the power effect; while the alternating power effect is very much less. The coiling of a wire produces a "choking effect" so far as the production of alternating currents is concerned, or acts as so much additional resistance would in the case of a direct current. The determining of this result is simply a matter of experiment. For example, a certain voltmeter and ammeter may be connected with the straight wire as indicated in Fig. 1, and 110 volts applied to the terminals of the arrangement as indicated. The ammeter will, if correct, indicate 11 amperes, for either direct or alternating pressure, and the actual power in each case will be 1210 watts. If now the wire be coiled into a coil about eight inches long with a two-inch diameter central hole, and an alternating pressure of 110 volts at 60 cycles be applied to the

Ohm's law. The alternating current in any coil may be expressed by the following general expression

$$I = \frac{E}{\sqrt{R^2 + (2\pi fL)^2}}$$

in which I denotes the alternating current, in amperes, E denotes the applied or impressed alternating pressure, in volts, R denotes the ohmic resistance of the wire constituting the coil (10 ohms for the coil just mentioned), L denotes the so-called coefficient of inductance, expressed in henrys, f denotes the frequency in cycles per second of the applied alternating pressure, and likewise of the resulting alternating current, and π has the usual value 3.1416.

While no indicating instrument can directly indicate the numerical value of L , the value may quite easily be obtained by experiment. Suppose a coil is connected with an alternating circuit, with a voltmeter, an ammeter and a frequency meter as indicated in Fig. 3. With the alternating pressure applied, the numerical values of I , E and f are indicated respectively by the ammeter, voltmeter, and frequency meter. Since the numerical value of the resistance R is known, the only unknown quantity represented by the symbols in the given equation is the coefficient of inductance L . The equation may be solved for L and expressed as follows:

$$L = \frac{\sqrt{E^2 - I^2 R^2}}{2\pi f I}$$

Assuming the numerical values already mentioned to obtain for a coil as represented in figure 3, E 110 volts, R 10 ohms, I 2 amperes, f 60 cycles, then the numerical value of L will be

$$L = \frac{\sqrt{12100 - 400}}{(377)(2)} = \frac{\sqrt{11700}}{754} = \frac{108.1}{754} = 0.14 \text{ henry}$$

It is evident from the last calculation that even one henry will act to reduce very greatly the numerical value of the alternating current in any circuit.

The next interesting consideration is that of the alternating current power. If the applied alternating pressure is 110 volts and the resulting current is 2 amperes, the resulting power cannot be greater than $110 \times 2 = 220$ watts. In order to increase this alternating-current power to 1210 watts which an applied direct pressure of 110 volts would produce, the applied alternating pressure at a frequency of 60 cycles, will need to be increased to over 605 volts. While a direct-current series motor will operate on an alternating-current circuit, the alternating pressure applied to the motor will need be very much greater than a direct-current pressure, in order to give the same output.

It has been stated that in an alternating current circuit as shown in Fig. 3, the power in watts cannot be greater than the product of pressure and current, but as a matter of fact the true actual power is always much less than this. This fact

can also be very easily demonstrated by experiment, with apparatus arranged as shown in Fig. 4. Here is shown a wattmeter for indicating the true power in watts, and a voltmeter and ammeter. In such an arrangement where there are coils of wire, the product of the ammeter and voltmeter indication is always greater than the correct indication of the wattmeter. That is, the product of the ammeter and the voltmeter indications will need to be multiplied by a factor or a number less than unity in order to have the same numerical value as the indication of the wattmeter. This multiplying factor is called the "power factor"; designated by $P. F.$ The power factor may be expressed as a fraction, or as a per cent by multiplying the fractional value by 100 and employing the symbol %.

The relation of pressure, current, watts, and power factor may be expressed simply by symbols as follows:

$$P. F. = \frac{W}{E \times I};$$

in which W denotes the indication of the wattmeter, and

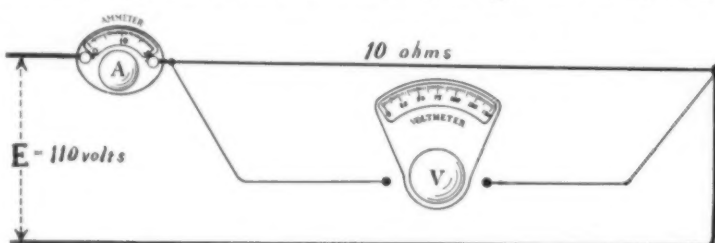


Figure 1

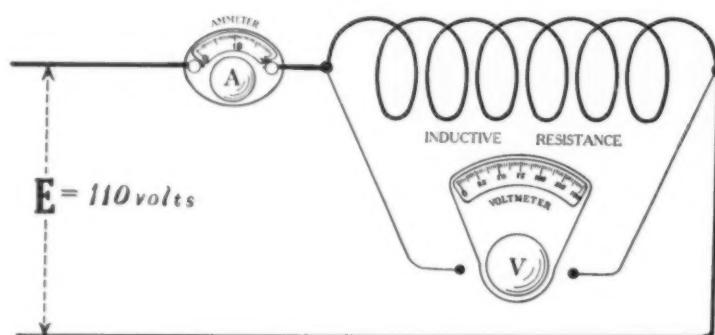


Figure 2

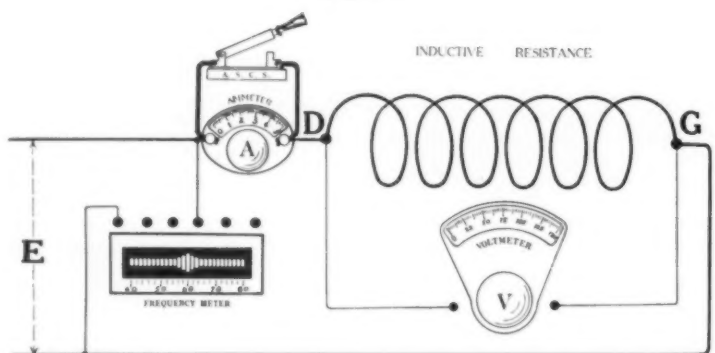


Figure 3

terminals, the alternating current in the coil will be about 2 amperes, while a direct pressure of 110 volts applied to the terminals of the coil will produce as originally a direct current of 10 amperes.

The ohmic resistance of the coiled wires is 10 ohms, exactly the same as before it was wound into a coil, so that the choking effect for alternating currents must be due to some agency other than resistance. The only other possible agency must be a counter electromotive force; that is, an induced alternating pressure that acts in opposition to the applied alternating pressure. Since such a counter pressure must be an induced pressure, it is called the counter electromotive force of induction, and the measure of the induced effect is called inductance. The effect of inductance is indicated by the symbol L and the unit of inductance is called the henry.

The current in a coil, due to the application of an alternating pressure, is not correctly expressed by Ohm's law as in direct-current engineering, but by what may perhaps be considered a modification of

E and I the indication of the voltmeter and ammeter respectively. If the numerical value of W is the same as the product of the numerical value of E and I then of course the power factor is unity or 100%. If a wattmeter should be connected with the straight wire shown in Fig. 1, the indication of the wattmeter would be the same as the product of the voltmeter and ammeter indications, and the power factor is unity. In other words, whenever unneutralized inductance exists in an alternating-current circuit, then the power factor is always less than unity.

Considering now the condition represented by Fig. 4, where the applied alternating pressure is 110 volts, the indicated current 2 amperes, and the indicated watts 96.8, then the power factor is

$$P. F. = \frac{96.8}{110 \times 2} = \frac{96.8}{220} = 0.44 \text{ or } 44 \%$$

The important consideration of the effect of the power factor from an efficient operative standpoint is the numerical value of the current that corresponds with any given useful power output.

From the last given numerical values, the applied pressure was 110 volts, and the true power 96.8; therefore from a direct-current standpoint the current necessary for the power output would be only

$$\frac{96.8}{110} = 0.88 \text{ ampere.}$$

This comparison leads to another consideration of power factor from the analytical standpoint that may be represented by the aid of a diagram; sometimes alluded to as a vector diagram, being made up of straight lines whose lengths denote the magnitudes of the quantities they represent, and whose directions indicate the relative directions in which the represented forces act.

For example, in Fig. 5 the line OA may represent a pressure of 110 volts while the line OB may represent a current of 0.88 ampere. The line OB is said to be in phase with OA and if the line OB represents an alternating current while the line OA represents an alternating pressure, the current is said to be in phase with the pressure. Now suppose the line OC represents by its length an alternating current of 2 amperes, while OA represents an alternating pressure of 110 volts. The position relation indicates that the current of 2 amperes is out of phase with the pressure, and is said to lag behind the pressure. Thus when the ammeter represented in Fig. 4 indicates 2 amperes, and the wattmeter indicates only 96.8 watts, the current is said to lag the pressure. The position of the line or vector OC representing 2 amperes, relative to the pressure vector OA has a very important bearing. Suppose a line as BD be drawn perpendicular to the pressure vector OA at point B, the end of the current vector; there can be but one position of the line vector OC so that the distance from O to the perpendicular is just 2 units in length; to represent 2 amperes. This fact establishes the angular relation of the current vector OC with the pressure vector OA. Also the length or vector OB is said to be the projection of the vector OC on the pressure vector OA. The angle between the current vector OC and the pressure vector OA is designated by ϕ and from trigonometrical relation the vector or projection OB is equal to $OC \cos \phi$ or $I \cos \phi$. Therefore instead of expressing the true power as indicated by the wattmeter as $0.88 \times E$, it may be expressed by

$$W = E I \cos \phi,$$

in which $\cos \phi$ denotes the "power factor."

By using the line OA as a diameter and constructing a semicircle as shown, extending OC to F, and drawing FA, the line OF represents the ohmic pressure drop in the coil, while FA represents the counter electromotive force of induction expressed by $2 \pi f L I$.

OF is perpendicular to FA; or the angle OFA is a right angle, since it is inscribed or included in a semicircle. This being the case, the principle of the Pythagorean Theorem may be applied to the diagram; which is that the square of the hypotenuse of any right angled triangle is equal to the sum of the squares of the other two sides. Hence the following must be true:

$$E^2 = (RI)^2 + (2 \pi f L I)^2 \text{ from which}$$

$$I^2 = \frac{E^2}{R^2 + (2 \pi f L)^2}$$

which corresponds to the initial equation of this article.

It is thus evident that wherever inductance is present, producing a power factor less than unity, a larger alternating current is present in the circuit or apparatus than is really necessary to produce a given power output. Every alternating-current motor has inductance due to the windings of field and armature coils, and

greatly augmented due to the presence of iron, which causes their power factor to be less than unity. This means that to furnish a required useful output in watts, larger currents are required than if the same output were furnished by direct-current motors, meaning either a greater loss of power in the transmission wires, or a greater interest charge on the cost of the increased amount of copper to prevent the increased loss. Because of the existence of inductance and its inherent power factor effects, alternating current motors for the same output weigh more than do direct-current motors.

The power factor of an alternating-current motor is not a constant; it varies considerably with variations in output. In the design of this type of motor the aim is to have the power factor as near unity as possible at as near the normal rated output as possible. If, however, such motors are used to furnish a small fraction of their rated output, during considerable intervals, the low power factors attendant upon partial output, results in unsatisfactory financial efficiency.

To illustrate the effect of power factor on the cost of copper for a motor or a transmission line having a power factor of 44 per cent. and an actual alternating

pressed by RI^2 . In the direct-current case, the loss is expressed by $R \times 88^2$ and in the alternating-current case by $R \times 200^2$. The ratio of the A. C. loss to the D. C. loss may therefore be expressed by

$$\frac{\text{A. C. loss}}{\text{D. C. loss}} = \frac{R \times 200^2}{R \times 88^2} = \frac{40000}{7744};$$

$$\text{or the A. C. loss} = \frac{40000}{7744} \times \text{D. C. loss.}$$

That is, the A. C. loss is over five times as great as the D. C. loss would be, in furnishing the same amount of useful power. In other words in order that the alternating-current system shall compete with the direct-current system, the cross section of copper must be five times as great, or five times as much copper will be required in the alternating-current system or motor as in the direct-current system.

Of course if the power factor were 80 per cent. instead of 44 per cent. the results would be very different. With the power factor 80 per cent. the actual line or conductor current would be

$$I' = \frac{176000}{200 \times 0.8} = \frac{17600}{160} = 110 \text{ amperes,}$$

in order that the actual useful power output remain at 17600 watts as when the power factor was 44 per cent.

The ratio of the two losses when the power factor is 80 per cent may be expressed by

$$\frac{\text{A. C. loss}}{\text{D. C. loss}} = \frac{R \times 110^2}{R \times 88^2} = \frac{12100}{7744} = 1.6;$$

or the A. C. loss = 1.6 times the D. C. loss.

Suppose at the same output of 17600 watts, the power factor is 90 per cent; then the line current must be,

$$I' = \frac{17600}{200 \times 0.9} = \frac{17600}{180} = 98 \text{ amperes.}$$

The fundamental principles explained in this article have very important application in the practical operation of mill motors. The conditions of operation at partial outputs, of various pressures, and the starting, stopping and reversal of motors will be the determining factors.

German Mining Operations in Serbia

Among the discoveries made by German engineers in Serbia during the war were 10 deposits of metalliferous ore, 2 of magnetite and 1 of asbestos. At Pustenik, northwest of Elshan, experimental work was carried on for some months with a view to exploiting serpentine asbestos, but had to be abandoned owing to the smallness of the deposits.

In July, 1918, experiments were commenced on a bismuth deposit at Gradiste, 15 kilom. south of Kulazevac. In the then occupied area work could only be carried out with the chromium deposits of Gorantza and Grechane. The copper mines and smelting works at Bor were left to Germany by Bulgaria to work for the duration of the war. The chrome-ore mines at Uskub, situated in the Vardar Valley, were worked by Bulgarians, while the Plakalnitza-Ellselsna Copper Mines and Works were operated under the authority of the Prussian War Ministry. Most of the copper ore was treated in a special furnace at the works.

The Proboda manganese mines at Posharevo were worked by the Bulgarian War Ministry, the Berlin Manganese Ore Co. supplying staff and materials for the purpose.—Z. des Ver. deutsch. Ingen.

Vulcanisation of Rubber at Constant and Increasing Temperatures

It is found possible to calculate and apply a series of rising temperatures such that the vulcanisation-time curve for any rubber-sulphur mixture may be made a straight line, the slope of which is dependent on the temperatures employed and the amount of catalyst present (compare this J., 1916, 643). To obtain the best physical properties by vulcanisation at constant temperature, sulphur must be present in the mixture in such amount that its active mass is not decreased sufficiently to diminish the rate of reaction appreciably before the desired vulcanisation coefficient is attained. With rubber-sulphur mixtures containing 5% or less of total sulphur, the physical properties of the mixture after vulcanisation at a series of rising temperatures are inferior to those given by vulcanisation at constant temperature; this is true particularly for vulcanisation coefficients of 2.8 or more. For Hevea rubber the optimum vulcanisation coefficient probably lies between 1.7 and 2.8. The coefficients recommended by various authorities are found to be excessive and unless the history of the vulcanisation phenomenon is fully known it is unsafe to judge samples solely on the basis of their sulphur content.—Journ. Soc. Chem. Ind.

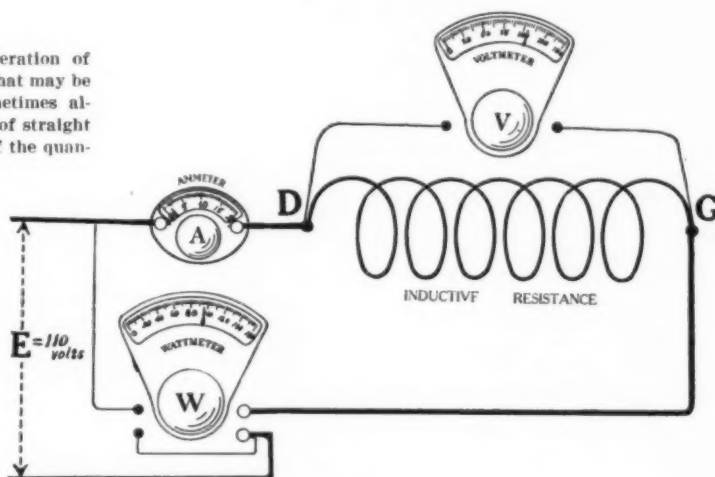


Figure 4

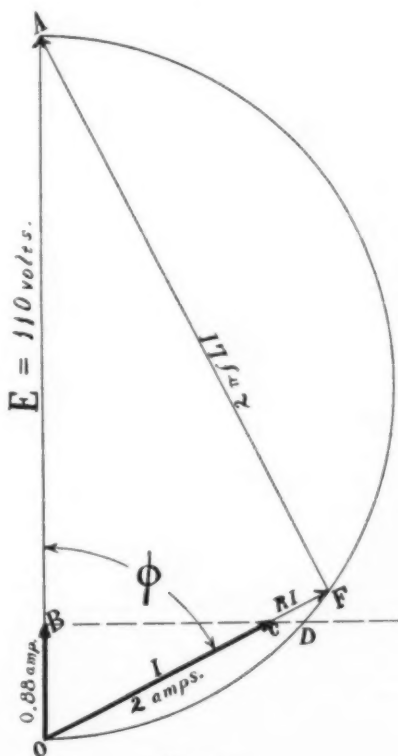


Figure 5

current of say 200 amperes, at 200 volts, is shown as follows. The true power is represented by

$$\begin{aligned} W &= E I \cos \phi = E I \times P. F. \\ &= 200 \times 200 \times 0.44 \\ &= 40000 \times 0.44 = 17600.00 \text{ watts} \end{aligned}$$

Were the power furnished by a direct current the current would be

$$\frac{17600}{200} = 88 \text{ amperes.}$$

The ohmic or heat loss in the copper conductor is ex-

Influence of Aluminum Ions on Seed Germination*

Experiments Upon the Relation Between Electric Conductibility and the Germination of Plants

By Julius Stoklasa in Collaboration with J. Sebor, W. Zdobnický, F. Týmich, O. Horák, A. Nemec, and J. Cwach

Editorial Note.—The following article describes the highly important results obtained by the late Dr. Julius Stoklasa at the Experiment Station of Physiological Chemistry connected with the Royal and Imperial Bohemian Technical High School in Prague. While the whole article is much too long for these pages we here present the gist of it together with details of some of the more important experiments.

Among the metals of the iron and aluminum group those most widely found in the vegetable kingdom are the biogenic elements iron, aluminum and manganese. Iron especially is always perceptible in the plant organism because it ranks among the most important biogenic elements. Aluminum is mostly found in the Hydrophytes and Hygrophytes and in a few cases in the Mesophytes. Aluminum is also found in certain Xerophytes in mere traces or in very small quantities.

Manganese, which was first discovered by Scheele in the ashes of various woods, appears to be present in all plants, while a few plants contain it in considerable quantities.

It is interesting to note that iron and manganese are always found in the above-ground parts of the plants, being localized especially in the leaves and flowers, while aluminum is mostly concentrated in the roots, rhizomes, root nodes, and bulbs of the more highly organized plants. All of these three biogenic elements are found both in the water and the earth and are absorbed as needed by the plant cells. It is of great interest consequently to investigate the mechanism by means of which these three biogenic elements are taken up through diffusion and through the permeability of the layer of plasma. Under certain conditions iron and manganese in weak concentrations favor the growth of plants, particularly the development of the chlorophyll apparatus.

In 1911 Julius Stoklasa presented a brief report of his researches before the French Academy of Sciences in Paris entitled "The Physiological Importance of Manganese and of Aluminum in the Plant Cell," in which he announced his discovery that aluminum is a protective substance and is indispensable to the life of plants. He found also that iron is capable of being absorbed in large quantities by plants only in the presence of aluminum. These experiments at once opened a wide perspective with regard to the phenomena of antedotal action or "detoxication" by means of the antagonistic action of the different ions (vide also the Coethen *Chemikerzeitung* of July 15th, 1911).

I find it convenient to divide the present article into three sections, namely:

I. The influence of aluminum ions upon the germination of seeds.

II. The influence of aluminum ions upon the development of plants.

III. Electric conductivity and its connection with the process of germination and the development of plants.

The Influence of Aluminum Ions Upon the Germination of Seeds.

In the experiments upon this subject pure uncrystallized salts of aluminum chloride and manganese chloride were employed. The chemical composition of both chlorides was tested to make sure of absolute chemical purity. The following concentrations were used: 0.05, 0.01, 0.005, 0.002, 0.001, 0.0005, 0.0002, and 0.0001 atomic weight of the aluminum or the manganese in the form of the chlorides in one liter of pure distilled water, the correctness of the concentration being determined by quantitative analysis.

The germination experiments were conducted in a thermostat provided with a thermo-regulator, the temperature being kept at 18° C. to 20° C. In order to prevent the concentration of the solution so far as possible from being altered through evaporation, the large dishes in which the experiments were carried on were protected by glass covers.

Each series of experiments lasted for ten days, the plants being measured separately at the end of the third, the sixth and the tenth day and the results compared with those from control plants. The time required for the exhibition of a difference between the latter and the plants being treated with the solution of aluminum or manganese chloride varied and was found to depend upon the degree of concentration of the salts. With a high degree of concentration of the ions an

unfavorable action was promptly observable, usually at the end of two days, while the very dilute solutions of the ions which were found to be requisite for producing a favorable and stimulating effect did not reveal their influence till somewhat later. However, a difference in one direction or the other in the various stages of development was nearly always shown between the third and the tenth day.

In order to prevent the growth of mold and fungi we followed Bokorny's practice in planting a few cress seed together with each of our test plants, since the former liberate vapors of mustard oil which prevents such growths. These cress seeds were placed beneath the topmost layer of paper upon which the testing of the seedlings was conducted, and by this method all fungus growth was prevented through the entire period of the experiment. The seeds were placed in large dishes 25 cm. in diameter and 7 cm. in height, the bottom of the dish being covered with filter paper. All the seeds were previously soaked for two hours in the solution to be tested or, in the case of the control plants, in distilled water 100 cubic cm. of the solution or of the water being placed in each dish. The dishes were weighed daily and the evaporated water replaced by an equal amount of pure distilled water.

At the end of ten days the roots and the above-ground portion of the plants were separated from the seeds, and the dry substance determined. Each experiment was repeated twice and an average of the results taken.

The influence of the manganese and aluminum chloride, both separately and in a mixture, was first tested upon barley (*Hordeum distichum mutans*, var. Bohemia Nole), then upon wheat (*Triticum vulgare multum*, red Bohemian Saatart), upon peas (*Pisum sativum* L.) and garden cress (*Lepidium sativum* L.). Seeds of the same size were chosen and their weight was approximately equal. Twenty-five seeds were planted in each experiment, but the seedlings were separated at the end of ten days from only twenty of these; they were then dried in the air and the weight of the dry substance determined. In those solutions with the higher degree of concentration of the ions the germinative power of the seeds was so strongly affected that only forty to sixty per cent. of them germinated. For the sake of the parallel tests twenty seeds were again taken and the stem or blade and roots separated as well as possible only from the seeds which had sprouted.

The tests with the barley were conducted from May 1st to May 11th, those with the wheat from May 12th to May 22nd, with the peas from May 24th to June 3rd, and with the garden cress from June 13th to June 23rd, 1916.

Here follow an elaborate series of tables giving the results obtained in the minutest detail. The reader will find these results summarized at the end of the article.

II.

The Influence of Aluminum Ions Upon the Development of Plants.

Great interest attaches to the solution of the problem as to what influence is exerted upon the growth and the entire development of plants by the aluminum ion, either alone or in the presence of the ferri-, ferro-, or, manganese ions. In studying this subject we examined Xerophytes (plants adapted to dry climates, such as the cactus), Hydrophytes and Hygrophytes (plants which live in water or marshy ground) and Mesophytes (plants which require balanced conditions of moisture and dryness). The selected and dampened seeds of approximately the same weight were first macerated for two hours in distilled water and then placed in a Linchart germinating apparatus which had been filled with sterilized sand, moistened with sterilized spring water. As soon as the seedlings had formed not only the main root and the plumula but also a few branch roots several centimeters long they were carefully removed from the germinating apparatus, cautiously rinsed with sterilized distilled water and further developed by means of the water culture method in a greenhouse. In favorable weather they were moved into an open space covered with a wire netting. In the study of Xerophytes two solutions were employed, one with and one without aluminum ions. In the latter there were present 1 gr. of potassium nitrate, 0.1 gr. of magnesium sulphates, 0.3 gr. of tricalcium phosphate, and 0.25 gr. of ferro-phosphate.

The other solution was of the same composition with the addition of 0.0005 to 0.003 atomic weight aluminum in the form of aluminum sulphate.

The greatest care was exercised to have the culture solution constantly exhibit a slightly acid reaction. A stream of air was passed through the solution daily in order to provide the root system with the oxygen required for the assimilation processes. At the end of twenty days of vegetation the glass cylinder was filled with a fresh solution. Each vessel had a content of 3,500 cubic centimeters. The following Xerophytes were made use of: *Alloisurus crispus*, *Polygonatum officinale*, *Iris bohémica*, *Stipa capillata*, *Stipa pennata*, *Polygonum viviparum*, *Spergula arvensis*, *Alyssum scutellum*, *Anthyllus vulneraria*, *Ornithopus sativus*, *Gentiana acaulis*, *Plantago arenaria*, *Biscutella laetigata*, etc.

The numerous Hydrophytes and Hygrophytes studied included the following: *Cystopteris fragilis*, *Polypodium vulgare*, *Glyceria aquatica*, several varieties of *Carex* and of *Ranunculus*, *Geranium pratense*, *Oxalis acetosella*, *Pulmonaria officinalis*, *Salvia glutinosa*, etc. The general results of these experiments with the above classes of plants may be stated as follows: the Hydrophytes and Hygrophytes are capable of supporting a stronger concentration of the aluminum ions than the Xerophytes. As we shall see later the aluminum ions are absorbed in much larger measure by the root system of the water loving plants than by that of the Xerophytes. The difference in the absorption of the aluminum ions is so extremely striking as to indicate very plainly that this ion must exercise a certain physiological function in the organism of the Hydrophytes and Hygrophytes.

Experiments With Mesophytes.—The plants were raised in a culture solution which was occasionally renewed. The solutions were as follows: (a) In 1,000 cubic cm. of distilled water were contained 1 gr. of potassium nitrate, 0.1 of magnesium sulphate, 0.3 gr. of tricalcium phosphate and 0.15 gr. of ferro-phosphate; (b) this solution had the same composition, with aluminum added in the form of aluminum sulphate in quantities ranging from 0.0005 to 0.003 atomic weight in the gram; (c) this was of the same composition, but iron was added in the form of iron sulphate in various concentrations ranging from 0.0005 to 0.004; (d) this was likewise of the same composition, but with manganese added in the form of manganese sulphate in quantities ranging from 0.0005 to 0.003; (e) this includes mixed solutions containing either the sulphates of aluminum and of iron or those of aluminum and of manganese.

The vessels in which the plants were grown had a content of 3,500 cubic centimeters and the experiments were carried on for several years in succession. It was in these experiments that the antagonistic or neutralizing action of the ions was observed, an effect which may also be termed "detoxication." Our experiments proved definitely that anomalies of metabolism are eliminated by the small quantities of aluminum employed as described above, so that the aluminum ion must be regarded as exerting an important detoxicating action. The weak concentrations of aluminum interfere most energetically with the absorption of the iron sulphates.

The results as a whole lead us to the conclusion that the detoxicating effect of the aluminum ion operates when the latter is present in very weak concentrations. The stronger the concentration the more evident the toxic effects.

All of our experiments led to the conclusion that neither iron nor manganese is capable of exerting this detoxicating action. The inhibition of the absorption of the single ions by the root systems of plants is a power possessed by aluminum alone.

It is not the molecule of the salt which is absorbed, but the separate ions. Connected with this taking up of ions and their physiological action is another important phenomenon, namely, the hydrolysis of salts which is particularly evident in the case of the trivalent metal ions.

III.

Electric Conductibility and Its Connection With the Process of Germination and the Development of Plants.

According to the well-known theory of Arrhenius all dissolved electrolytes, acids, bases, and salts are more

*It is necessary here to omit the tables whose results we give further on.

*Translated from the *Biochemische Zeitschrift* (Berlin) for the SCIENTIFIC AMERICAN SUPPLEMENT.

or less split up into their ions and their solutions, i. e., are dissociated. If a salt consists of a metal ion M and an acid ion S an equilibrium will be formed in the solution between the dissociated parts and the non-dissociated parts; we will then have in the solution not a molecule of the electrolyte, but the mass parts, and these must be taken into consideration in the development of osmotic pressure.

Another result of the dissociation of the electrolyte is that in the labile condition in which the ions find themselves the following reciprocal actions may occur:

1. Reciprocal influencing of the degree of dissociation.
2. Reciprocal exchange of the ions in the different electrolytes.
3. The hydrolytic splitting up of the water by means of the ions.
4. An influencing of the colloids which are eventually present.

1. *The Influence of the Degree of Dissociation.*—When two electrolytes have an ion in common a condition of equilibrium arises in the dissociation between the two. . . . two electrolytes with a common ion reciprocally lower the degree of dissociation of each other. When not only the anions but the cations of the salts are different a mutual exchange takes place, and in this case all four combinations of ions may come into play. In such a case it is to be expected that in consequence of the lowering of the concentrations of the component parts, since no important lessening of the degree of dissociation takes place, no especial influencing of the physiological effect will be observable in the salt mixtures. As a matter of fact in mixtures of aluminum, iron and manganese salts with different anions a smaller antagonistic influencing of the effectiveness of both salts is perceived.

2. *Reciprocal Exchange of Ions.*—The process of the mutual exchange of ions in the solution of two electrolytes is a very general phenomenon and is of special significance in the solution of bases; of particular importance in this respect are the bicarbonates of sodium, potassium, calcium and magnesium formed by the dissolving power of the carbon dioxide. Between them and the other salts an equilibrium is established which is of importance with respect to the taking up of the separate ions, e. g. with the salts potassium chloride and calcium carbonate the equation of the equilibrium reads as follows: $2KCl + Ca(HCO_3)_2 = CaCl_2 + 2KHCO_3$. A similar condition of equilibrium arises between the other salts of the culture solution. . . . This mutual exchange of ions between the different electrolytes gives us in part the explanation of the quantitative power of choice exhibited in the mechanics of the absorption of the ions through the root system of plants.

3. *The Hydrolysis of Salts.*—When either the base or the acid which can be split off in an electrolyte is weak, then a hydrolysis of the salt is set up in the solution. . . . The hydrolysis is proportional to the square root of the molecular value of the medium of solution as proved experimentally by Shields.

4. *Dissolved Colloids.*—Hydrolysis by water is particularly important when it causes the formation of compounds which possess the properties of colloids or resemble these. Thus, the basic salts, especially those of the organic acids of aluminum and iron, are colloidal in character. Since now these colloidal substances are formed by hydrolysis, especially in the presence of the bicarbonates of the earthy alkalis, from the salts which are but slightly capable of diffusion it follows that the greater the hydrolysis of the salt the more difficult of diffusion the aluminum and iron compounds. . . . and in this condition they can be most readily held fast by the tissue of the roots.

The Degree of Dissociation of the Electrolyte and Its Effect Upon the Process of Germination.

To sum the matter up it was found that very dilute solutions of the chlorides of aluminum and of manganese as also of their mixtures have a stimulating effect upon the germinative process of various seeds, and also increase the production of the vegetable substance. This catalytic influence is connected with a series of physical and chemical phenomena. The effective cation acts as follows:

1. Passes through the cell membrane by means of diffusion;
2. Alters the character and properties of the skin of the cell;
3. After having penetrated the cell exerts a catalytic influence upon its vital processes.

I.

The diffusion of salts in aqueous solutions through cell membranes is governed in general by the law of osmotic pressure, i. e. the diffusion is directly proportional to the osmotic pressure of the substances in

solution. In the case of electrolytes, however, we must take into consideration the electrolytic dissociation since through this the quantity of the effective particles of matter is increased. . . . It has been discovered that the greater the degree of dissociation in an electrolyte, the greater the osmotic pressure, but since the electric conductivity is dependent upon the degree of dissociation the osmotic pressure can be found by determining the electric conductivity. . . .

On this account a comparison was suggested between the physiological effect and the corresponding conductivity of solutions. It was established, however, that while there is a parallelism between these two phenomena there is no direct dependence of one upon the other—which indeed could not have been expected. The results obtained were as follows:

1. In those solutions in which the degree of dissociation was highest, the substances exerted a stimulating effect and the largest amount of plant mass was produced, which indicates a significant degree of osmosis of the dissolved substances.

2. Substances formed by the plant cells, such as the hemicelluloses, the pectins, etc. absorb cations, such as the aluminum, manganese, and ferro-ions, and form compounds with them which are less soluble or less permeable.

3. The manner in which the catalytic influence of the diffused cations in the cell operates, cannot as yet be fully explained since neither the separate processes nor the catalytic influence of the various cations upon the processes of the germination and development of plants are as yet clearly understood. It may be said, however, that the physiological action of the cation is the result of all the physical and chemical processes concerned in the said germination and development.

Stoklasa² has propounded in one of his latest works a theory regarding the physiological effectiveness of the various salts upon the development of plants in the form of a mathematical diagram. In this the attempt is made to apply the theory to the catalytic operation of the chlorides of aluminum and of manganese.

[Since the mathematical tables and diagrams herewith given are unsuitable for these pages, though interesting to advanced students of the physiological chemistry of plants, we omit them and content ourselves with quoting the summary of results, which closes the article.—Editor.]

CONCLUSIONS.

The most important conclusions derived from the preceding experiments may be formulated in brief as follows: The results of our researches concerning the influence of aluminum ions and of manganese ions upon the process of germination of the seeds of the Mesophytic plants are stated below.

1. Experiments with aluminum in the form of *Aluminum Chloride*.—A concentration of 0.0001 to 0.0002 (atomic weight) per gram of aluminum in the form of aluminum chloride, not only exerted a favorable effect upon the germinating process of the seeds treated with it as compared with the germination of the controlled seeds in pure distilled water but also occasioned a greater yield in the total mass of plants after a period of development of ten days, as shown in all the plants tested, i. e. the *Hordeum distichum*, *Triticum vulgare*, the *Pisum sativum*, and the *Lepidium sativum*.

With 0.0005 atomic weight aluminum in the form of aluminum chloride the energy of germination was somewhat retarded and the production in the total mass of plants was not so great as in the previous degree of concentration, although an increased yield was still to be observed in comparison with the control plants.

With a concentration of 0.001 atomic weight of aluminum per gram in the form of aluminum chloride, both the capacity for germination and the energy of germination were lowered; this degree of concentration caused a perceptible diminution of the total plant production in the ten-day-old seedlings.

This toxic effect was increased still more when the atomic weight of the aluminum was doubled, i. e. increased to 0.002, and the effect was still more marked when the concentration was increased first to 0.005 and then to 0.01. In short the stronger the concentration the more intensive the toxic effect upon the capacity of germination and the energy of germination, as well as upon the entire development of the seedlings.

2. Experiments with Manganese in the form of *Manganese Chloride*.—With a concentration of 0.0001 to 0.0005 atomic weight per gram of manganese, in the form of manganese chloride in pure distilled water, the whole process of germination as well as the energy of

germination were very favorably influenced. Furthermore, there was a considerably increased yield with respect to the plant mass after ten days of development.

With a concentration of 0.001 of the same solution certain plants such as *Hordeum distichum*, *Triticum vulgare*, and *Lepidium sativum* were favorably affected, but in *Pisum sativum*, on the contrary, the solution already betrayed a toxic action and a lessened yield in plant mass was observed.

With a concentration of 0.002 of atomic weight manganese in the form of manganese chloride per gram per liter an injurious effect was exerted upon the process of germination and the energy of germination and resulted in a reduced yield of plant mass. A concentration of 0.005 exerted a still more depressing effect, while a concentration of 0.01 began to be perceptibly toxic and this toxic effect became still more marked in stronger concentrations.

3. *The Effect of the Two Chlorides and Especially of the Aluminum Chloride and the Manganese Chloride.*—The antagonistic effect of the ions was fully exhibited when manganese chloride of a concentration of 0.005 and aluminum chloride of a concentration of 0.0001 were employed.

The depression in the energy of germination revealed by the 0.005 manganese concentration was counteracted by the 0.0001 concentration of the aluminum chloride. In this case, too, an increased yield in the plant mass was observed.

With a concentration of 0.005 of the manganese and 0.0002 of the aluminum the antidotal effect was much more energetically exhibited than in the previous experiment. With a concentration of 0.005 of the manganese and 0.0005 of the aluminum the antidotal effect was also very evident. But with the same concentration of the manganese and 0.001 of the aluminum the antidotal effect did not appear. On the contrary the toxic effect was quite perceptible in all the sprouting plants with the exception of the *Lepidium sativum*. With the same concentration of manganese and 0.002 of the aluminum the inhibiting effect upon the toxicity of the aluminum ion was entirely suspended in the case of the *Hordeum distichum*, *Triticum vulgare* and the *Pisum sativum*; the antidotal effect was exhibited, in fact, only upon the *Lepidium sativum*.

With the same concentration of manganese and 0.005 of the aluminum no antidotal effect of the aluminum was perceived. All of the seedlings exhibited a decrease in yield at the end of the ten days' growth. With the same increase of manganese at 0.01 of the aluminum the toxic effect of both ions was strongly marked. These degrees of concentration caused a marked decrease in the production of the organic matter and the antagonistic action of the ions and, therefore, the mutual checking in the taking up of two ions having the same kind of electric charges was completely inhibited at these degrees of concentration.

Strong concentrations of aluminum chloride and manganese chloride exert a poisonous action, therefore, reducing the production with respect to the living plant mass.

4. *The Action of Aluminum Ions Upon Xerophytes.*—With a concentration of 0.001 of aluminum in the form of aluminum sulphate per liter of the culture solution a poisonous effect was observed at the end of twenty-four days, resulting in a retardation in the development of the plants. With a concentration of 0.002 of the same solution a toxic effect was observed from the twenty-first day to the thirtieth day of growth; however the plants did not die. With a concentration of 0.003, however, all the plants died at the end of eighteen days.

5. *The Hydrophytes and Hygrophytes Exhibit Great Resistance to the Action of Aluminum Ions.*—Concentrations of 0.0005 and 0.00075 of aluminum in the form of aluminum sulphate produce a favorable effect upon the development of Hydrophytes and Hygrophytes as compared to those plants which developed in a culture solution which contained no aluminum ions. 0.001 of the aluminum in the form of aluminum sulphate per liter of the culture solution produce a beautiful and luxuriant growth in the *Carex riparia*, *Carex vesicaria*, *Carex silvatica*, *Ranunculus fluitans*, *Galeopsis versicolor*, and *Callitha palustris*, as compared with the control plants. No injurious effect was observed in the plants at the end of forty-eight days with a concentration of 0.002 to 0.006 of the aluminum. A concentration of 0.0075 of the aluminum exerted a slightly harmful effect upon the *Ranunculus arvensis*, *Callitha palustris*, *Symphytum officinale* and *Pulmonaria officinalis*. 0.0095 of the aluminum somewhat retarded the development of *Rumex acetosella*, *Ranunculus fluitans*, *Ranunculus arvensis*, *Callitha palustris*, *Geranium pratense*, *Pulmonaria officinalis* and *Symphytum officinale*.

Great resistance was shown by the different kinds of

²Julius Stoklasa. Contribution to the Study of the Nutrition of the Sugar Beet. Physiological Significance of the Potassium Ion in the Organism of the Sugar Beet, p. 207. Published by Gustav Fischer, Jena, 1916.

Carex, especially *C. riparia*, *C. venicaria*, *C. silvestris*, and *Galopis versicolor*. In the above plants no toxic effect was noted until a concentration of 0.02 was reached, at which time the development was greatly retarded while a few specimens of the *Rumex acetosilla*, *Ranunculus arvensis*, *Caltha palustris*, *Geranium pratense*, *Pulmonaria officinalis* died at the end of twenty to thirty-seven days. The *Carex* were retarded but not killed. However, even these were destroyed from the tenth to the twentieth day with a concentration of 0.05.

6. *Influence of Aluminum Ions on the Development of the Mesophytes*.—In the first series of experiments it was noticed that the presence of a 0.0005 concentration of aluminum in the form of aluminum sulphate in one liter of the culture solution caused an increase in the plant mass at the end of seventy-two days of development in the cases of *Triticum vulgare*, *Avena sativa*, *Hordeum distichum* and *Polygonum fagopyrum*. A slight decrease of plant mass occurred in the *Secale cereale*. In the second series of experiments increase of yield was exhibited in all cases. A concentration of 0.0005 of iron in the form of sulphate of iron per liter of the culture solution caused a reduction of plant mass in the *Triticum vulgare*, *Secale cereale* and *Avena sativa*. A slight increase occurred in the *Hordeum distichum* and *Polygonum fagopyrum*.

The production of plant mass was distinctly increased by the presence in one liter of the culture solution of 0.0005 of aluminum and of iron each. Increase in the plant mass was caused in all cases by the presence of 0.00075 of aluminum per liter. But the same atomic weight of iron, on the contrary, caused a decrease in the formation of plant substance.

But when both ions were working together no disturbances in the metabolism were to be observed and there was a marked increase of production. With a concentration of 0.001 of the aluminum there was little alteration observed in the first series of experiments while there was a slight increase seen in the second series. With 0.001 of iron on the other hand there was a decrease in the plant mass.

In the presence of both ions and with a concentration of 0.001 the antidotal effect was observed in all cases except the *Hordeum distichum* (barley). A decrease in the plant mass was caused by a concentration of 0.002 of the aluminum and the same concentration in the case of the iron ion was still more toxic. But when both the aluminum and the iron ions were present in the 0.002 concentration a slight antidotal effect was perceptible.

But as soon as the experiment was made with the above concentration of iron and only 0.0005 of the aluminum the neutralizing effect became very marked. In other words the irregularities of metabolism were eliminated by these small quantities of aluminum, and it was at once evident that the aluminum ion is capable of producing a notable detoxicating effect.

7. It is obvious, therefore, from the results of the above experiments with aluminum and iron, that just as in the case of aluminum and manganese 0.005 atomic weight of aluminum has a favorable effect upon the development of vegetation and the same amount of manganese in the food solution also favored growth, while like amounts (0.0005) of both aluminum and manganese caused a marked increase in plant mass.

Similar results were obtained with a higher concentration, 0.00075, of the aluminum alone and the same amount of the manganese alone.

The most luxuriant growth and the greatest yield of plant mass was obtained when both ions were present in a concentration of 0.00075.

A concentration of 0.001 of the aluminum also favored growth and a like amount of manganese also caused a small increase in yield. When both ions were present in this degree of concentration a small increase as compared with the control plants was evident at the end of seventy-two days of development. But there was a marked decrease observable when both ions were present in a concentration of 0.002; in this case there was a notable retardation in the development of the plants and the antagonistic action of the ions was lacking.

The same amount of manganese also caused a decrease of yield, but when to this was added 0.0005 of the aluminum a strong detoxicating effect was perceptible and thus there was a markedly favorable action upon the growth.

This antagonistic ion action is evident, namely, whenever the food solution containing 0.003 of iron or of manganese was used in combination with 0.0005 of aluminum. But in higher concentration of the aluminum ions the detoxicating action begins to diminish and ceases with 0.0015 of the aluminum.

All the further experiments carried out by us indicated that neither iron nor manganese is capable of

evoking the reciprocal detoxicating action. The aluminum ion alone is capable of inhibiting the taking up of the ferro-, or the ferri-, and manganese-ions on the part of the root systems of plants.

8. In observing the toxicity of the aluminum ion we find that 0.005 atomic weight aluminum in the form of the sulphate per liter of the food solution greatly retards development while with a concentration of 0.01 all the plants died from the nineteenth to the twenty-fourth day.

With respect to the poisonous property of iron it may be said that symptoms of a toxic effect upon the protoplasm are produced by a concentration of 0.005 atomic weight iron in the form of the sulphate; furthermore a shortening of the vegetative leaf forming phase is observable. With a concentration of 0.006 of the iron the plants died in from fifteen to twenty-one days.

The poisonous action of manganese showed itself as follows: 0.008 of the manganese in the form of manganese sulphate entirely killed all the plants after from twelve to twenty days of vegetation.

9. *General Principles Deduced*.—The following principles have been deduced from the researches described above:

(a) A general mathematical expression for the vegetation curves was deduced and verified by the results of experiments.

(b) A theory was evolved concerning the physiologic action of chemical agents and in consonance with this theory the effective factors of the separate ions were determined and also the degree of effectiveness for each.

(c) The electric conductivity of the solutions in question at 18° C. was determined, and this was done not only for aluminum chloride, aluminum sulphate, manganese chloride, and manganese sulphate solutions, but also for mixtures of these. These results were compared with the quantitative results obtained in the germination of seeds and in the development of plants. A comparison was instituted between the degrees of physiological effect of the ions and the degrees of disassociation of the salts and it was found that the greater the effective factors the more sensitive the plant to the catalytic effect.

(d) The fact was established that the organism of the seedlings of the Mesophytes is more sensitive as a general rule towards aluminum ions than towards manganese ions. It was found, further, that the developed plant is less sensitive to the aluminum ion than to the ferro-, ferri-, and manganese-ion. This phenomenon is explained by the fact that in the developed plants aluminum becomes localized in the root system, while iron and manganese become localized in the chlorophyll. In the root system of the more highly organized plants the exchange of ions acquires its full significance. In the seedlings, however, the aluminum is present throughout the whole organism and produces toxic effects. Besides the disassociation the hydrolysis also appears to exert a strong toxic effect upon the germination; the hydrolysis increases with dilution of the aluminum solution, and (as a consequence) an increasing concentration of the hydrogen ion.

This influence of the hydrogen ions is exhibited in the manganese ions only in a subordinate degree.

In the mixtures the effect exhibited was less than the sum corresponding to the separate ion concentrations. It was noted especially that the aluminum ion produces a decrease of the injurious effect caused by the ferro-, ferri-, and manganese-ions.

(e) An extensive parallelism was established between the degree of the physiological effect and the degree of disassociation; in other words the conductivity of the chlorides and the sulphates of aluminum and of manganese and of their mixtures. Likewise it was found that the chlorides of aluminum and of manganese as well as the sulphates of aluminum, iron, and manganese bring different effective factors into operation in the different plants, and that the catalytic effect of the cations is directly proportional to the effective factor.

However, the operation and the degree of activity exhibited by the various effective factors in different concentrations is very similar both as to the different plants and the different salts. This phenomenon resembles the established facts of the lowering of the electric conductivity and disassociation in the mixtures of the chlorides of aluminum, iron and manganese, as also of the sulphates, as compared with the disassociation of the separate salts alone.

At Pompeii and St. Pierre

(Continued from page 315)

Indenting plug might be widely conical with a spiral ridge. There could be used also containers set with a spring plug that would allow entrance of air or gas at given pressures but stopped for egress. These if

exhausted when set would keep air samples and might retain their maximum pressure.

Duration of pressure might be obtained by a timing mechanism within a strong capsule which would be released for motion while the pressure is acting on the plates of the container.

Temperatures and heat would probably be best registered by their effects on exposed objects since the action may be too speedy for other registration. Thermopiles might be arranged to register their throw or to indent their difference of expansion.

The whole matter is in a formative stage. That heat of compression is the large fatal factor to man exposed to eruptive volcanoes seems most probable, for the explosions are probably great enough to produce a pressure wave capable of heating the air to 60° C. or more for miles from the source. That this compression ignited buildings and ships, crushed in the hatches of the steamship *Roraima*,⁷ denuded trees and shredded their pulp, is almost as evident. Furthermore, nicely-graded effects could not have been accomplished by the ravage of hot or flaming crater gases.

⁷Chief Engineer Scott, Eruption of Mount Pelée, Cosmopolitan, July, 1902, p. 250.

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